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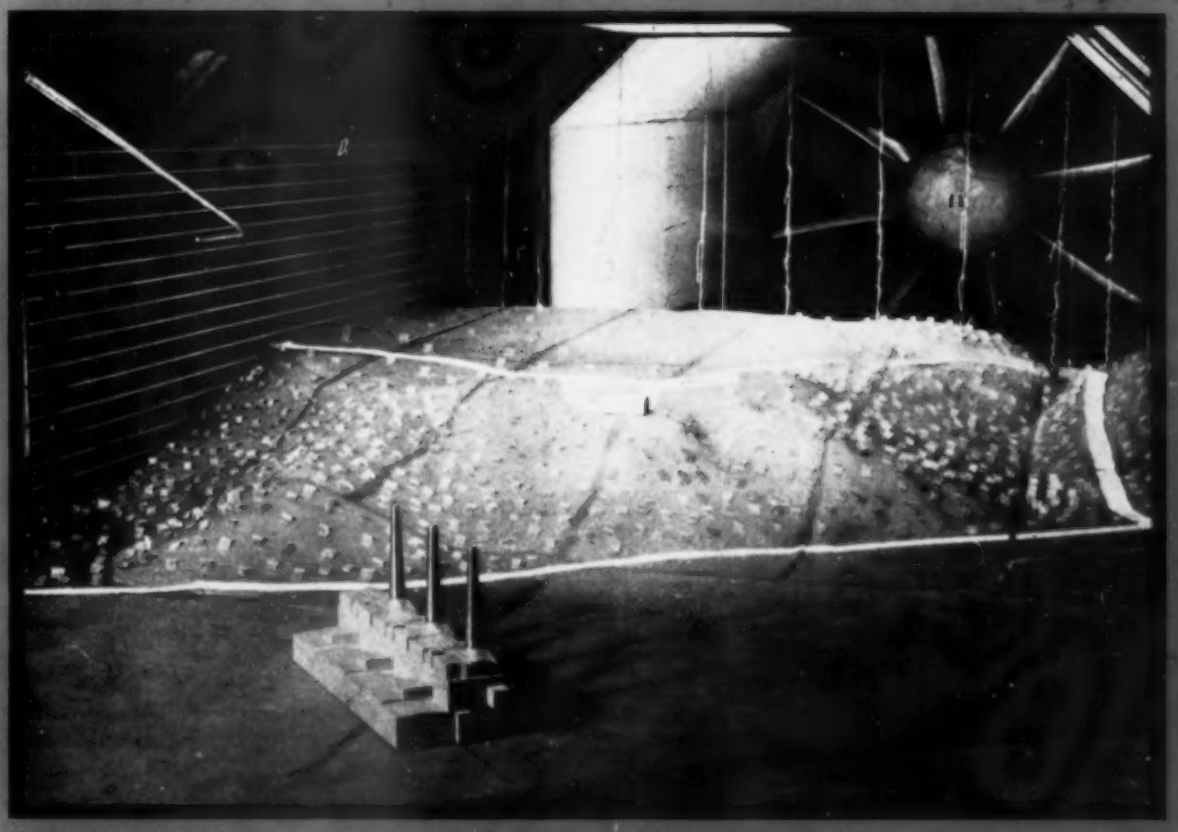

University of Michigan wind tunnel: see page 54

Inert Gas Welding of Pipe and Tubing ▸

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4 reasons why...

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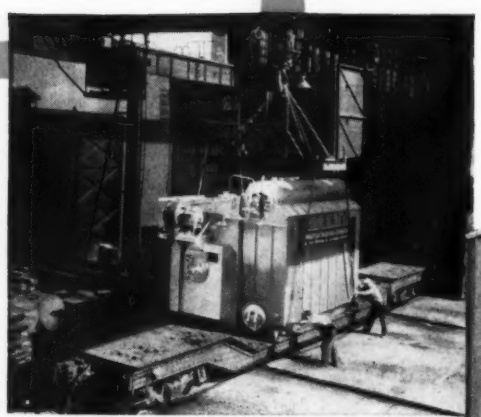

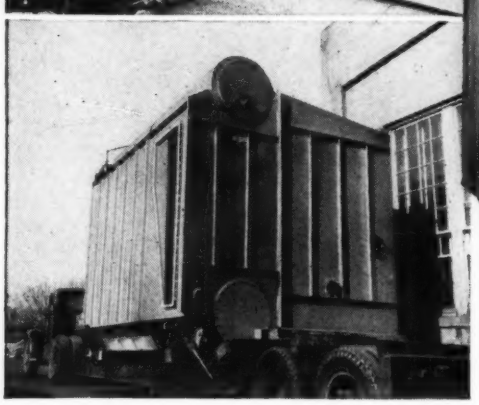

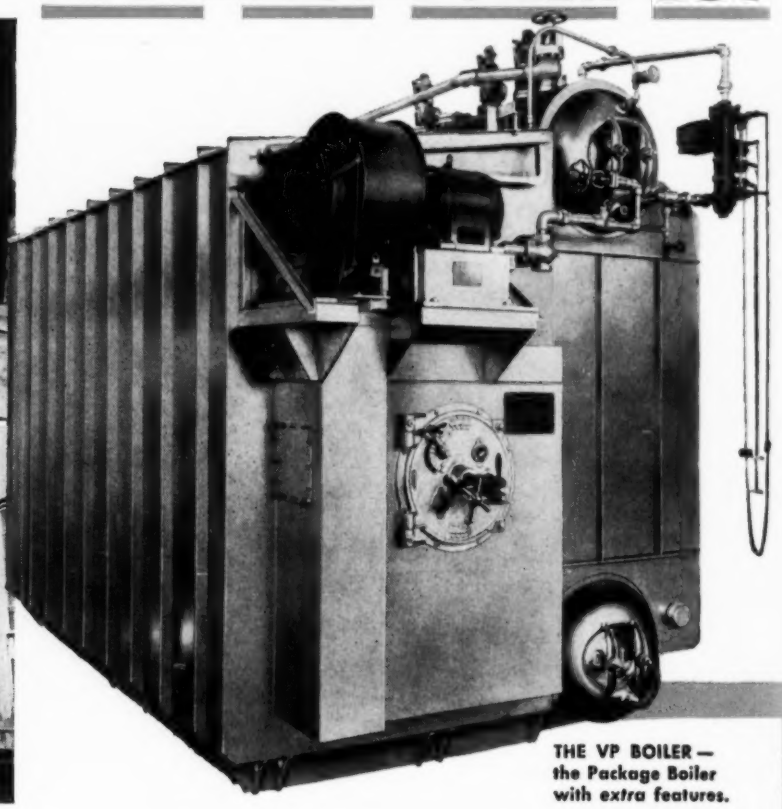

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COMBUSTION ENGINEERING, INC.

200 MADISON AVENUE, NEW YORK 16, N. Y.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT

Editorials

A Message to Readers

As of December first I became eligible for retirement as Editor of COMBUSTION. The twenty years served in this capacity have covered a period of unprecedented progress in the field of steam power and it has been a privilege to record and interpret much of this development to readers. They have been years of pleasant company and reader relations.

By retiring, I am not unmindful that I shall miss the many contacts which form an integral part of an editorial career, but trust there will be some compensation in the opportunity thus afforded to do certain things that heretofore have been precluded by lack of time. However, from the sidelines I shall view with keen interest the further progress in power generation.

In turning over the editorial responsibilities to my successor, Joe McCabe, I am confident that they will be in competent and experienced hands. He and Glenn Fryling, my able associate for the last five years, who is personally known to many readers, should provide a team that will carry COMBUSTION to still greater success.

A. W. Blake

Alfred D. Blake

Joseph C. McCabe

Glenn R. Fryling

Changes in Combustion's Editorial Staff

On the editorial page of this issue, Alfred D. Blake tells in his own words of his retirement and of the satisfaction he has had in serving as Editor of COMBUSTION for the past twenty years.

It is only a little more than a year ago that I had the pleasure of congratulating Al in this column on his being made a Fellow of the American Society of Mechanical Engineers. The following citation read at the time of the Fellowship Award is quoted here both as a brief review of Al's career and as a fitting recognition of his distinguished contribution to engineering journalism.

"Alfred D. Blake is a graduate of Cornell University with an M.E. degree. He began his engineering career with Westinghouse, Church, Kerr, consulting engineers, was associate editor of *Power* and served in the United States Army during World War I with the rank of Major. After the war he returned to *Power* where he rose to managing editor. Later he served briefly as editor of *Steam Plant Engineering*. In 1933 he joined Combustion Publishing Company and has been editor of COMBUSTION since that time.

"Mr. Blake has guided the editorial policy of COMBUSTION so well that power engineers regard that publication as one of the outstanding technical journals in the world. Its articles have been authoritative and have made major contributions to technical development."

We know that COMBUSTION's many readers who know Al personally, as well as those who know him only through his writings, will join with us, his associates, in the hope that he will have many happy and healthful years of freedom to pursue his various interests in the leisurely fashion which one can only achieve in retirement. That these interests will include keeping in understanding touch with developments in the power field is a certainty, and we hope that out of this from time to time will come an article in COMBUSTION over the familiar and revered name of Alfred D. Blake.

We are indeed happy to welcome, as Mr. Blake's successor, Joseph C. McCabe. Mr. McCabe brings to the post of Editor a fine educational and experience background. Following a year at Newark College of Engineering, he attended Lehigh University for four years, graduating with a B.S. in Electrical Engineering, and the Graduate School of Stevens Institute of Technology for two years. He then spent seven years in power plant work in plants of the Jersey Central Power & Light Company. From 1943 to the close of the war he served as a field engineer for Western Electric company in the U. S. Army Airborne Radar, overseas. In late 1945, he joined the McGraw-Hill Publishing Company where for the past eight years he has been an Associate Editor of our esteemed contemporary, *Power*.

We are also happy to announce that Glenn R. Fryling, Assistant Editor of COMBUSTION for the past five years, will share editorial responsibilities with Mr. McCabe in the new post of Associate Editor. Mr. Fryling has a B.S. degree from Bucknell University and served briefly as an instructor in Electrical Engineering at Rutgers. He has had several years of experience in the consulting field with Jackson & Moreland and Westcott & Mapes.

Both Mr. McCabe and Mr. Fryling have been active in engineering society work as members of the ASME, where Mr. McCabe is a member of the Executive Committee of the Fuels Division, while Mr. Fryling serves on the Meetings Committee. Related interests are reflected in Mr. McCabe's chairmanship of the Air Pollution Control Committee of the National Association of Power Engineers and Mr. Fryling's membership in the American Society for Engineering Education.

With this editorial team, we believe COMBUSTION can look forward confidently to a continuance of the high standards of engineering journalism so successfully developed and maintained by Al Blake during his long tenure as Editor.

Charles McDonough

Vice-Pres., Combustion Publishing Co., Inc.

Inert Gas Welding Applied to Pipe and Tubing

This article gives general information concerning one of the newer welding processes as used in the welding of pipe and tubing. The inert-gas welding processes are widely used in many more applications than the specific ones discussed here.

By R. E. LORENTZ, Jr.

Combustion Engineering, Inc., Chattanooga, Tenn.

ALL the steels used in power plant equipment from rimmed carbon steel to austenitic alloy steel are weldable with the inert gas process. In addition, aluminum, copper, nickel, and their alloys and, in fact, most all metals are weldable with this process. The two main processes are those which employ either a non-consumable electrode or a consumable electrode.

With the former the electrode is usually tungsten or thoriated tungsten, but may be carbon in certain instances. The arc is struck between the electrode, which

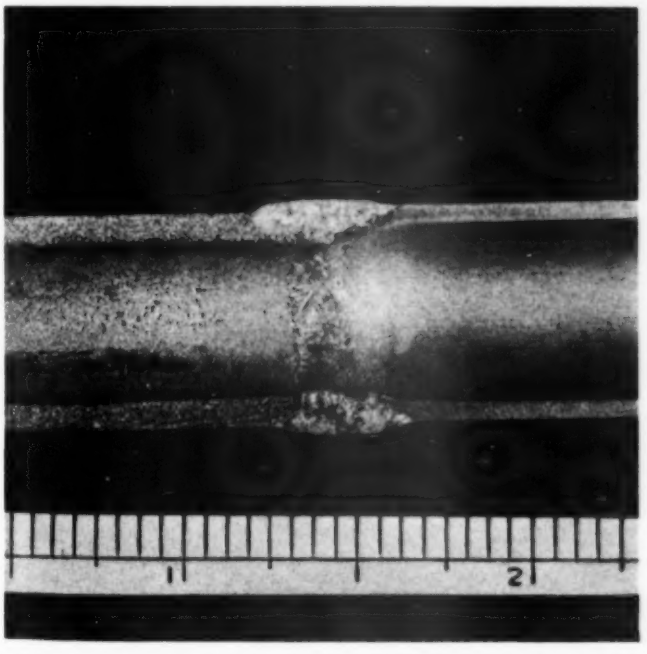

Fig. 1—Section through weld of 5/8-in. OD Type 304 stainless tubing, 0.095-in. wall on left, 0.065-in. wall on right; 0.065-in. wall swedged to same ID as 0.095-in. wall. Three-pass manual inert-gas weld, last two passes with filler metal.

is surrounded by an inert gas atmosphere such as argon, helium, or combination, and the work. Filler metal may be added separately by melting under the arc or no added filler metal may be required.

With the latter the electrode is filler metal of analysis required. The arc is struck between this electrode, which is surrounded by inert gas atmosphere, and the work. The arc length is maintained by automatic feed of the filler metal as it melts.

General Advantages

The non-consumable process can use tungsten electrodes of diameters of 0.025 in. and less. These small

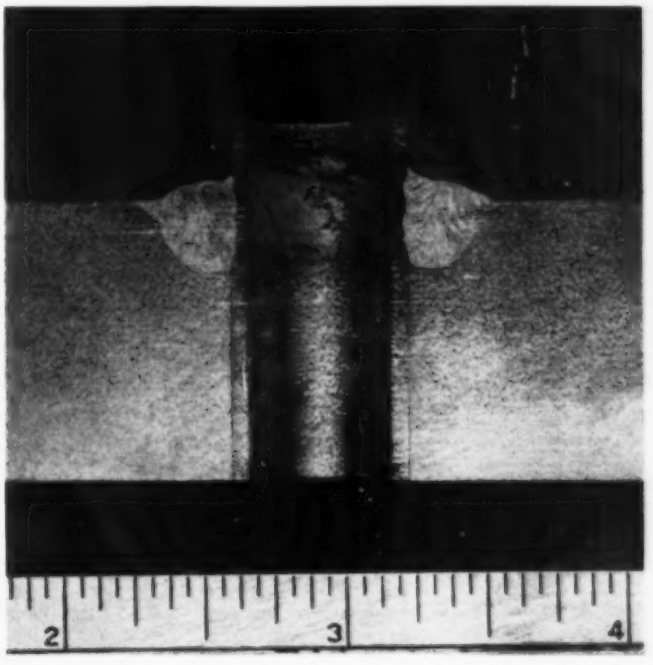

Fig. 2—Three-pass manual metal-arc coated-rod weld

electrodes allow the holding of an arc of 5 to 10 amp, or higher. The advantages of this small amperage concentrated in a very small-diameter, very high temperature arc, for many applications is evident. On the other extreme, electrodes larger than $^1/_4$ in. diameter can be used with high amperages for applications requiring large heat inputs.

Because of the inert gas atmosphere, loss from the molten pool of easily oxidized elements is minimized and there is no slag or molten flux with which to be contended.

Because the electrode is relatively non-consumable, the arc length can be held manually with more ease than with a consumable electrode which must be fed into the molten pool when manually holding an arc. Because the arc is visible, it can be directed to proper location.

All of the foregoing adds up to the general advantage of "close control" which this process gives.

The consumable process uses, at the present time, bare rods from 0.015 in. diameter and larger. This process is used generally for welding of thicker materials than the non-consumable process. This is because high current densities are required for smooth operation of the equipment. As filler metal is fed from a continuous coil, arc starts and stops are minimized. Because of high current densities, high deposition rates can be obtained. Cost

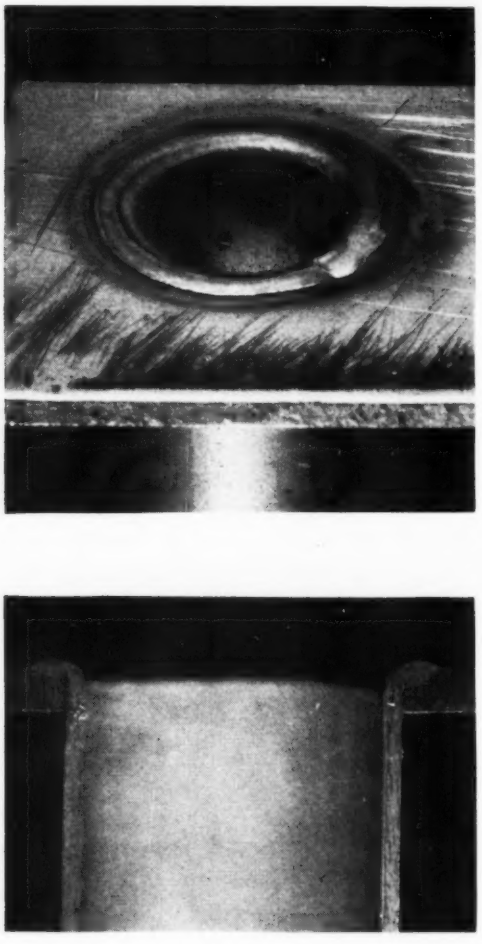

Fig. 3—One-pass manual inert-gas-seal weld. Top view shows weld surface; bottom shows cross-section.

savings from this must be balanced against present high cost of atmosphere gases.

Specific Applications

1. Single-Pass and Multiple-Pass Welds

Longitudinal butt welds in piping or tubing using the inert gas process are made with automatic welding and skelp-forming equipment. The welds may be single pass or multiple pass. Proper production control results in consistently high quality welds. Fit up of parts, cleanliness of parts, uniform travel speed, amperes, volts, and atmosphere must be meticulously controlled and generally are in tonnage operations. In the fabricating shop, where custom welding is being done, the same variables must be meticulously controlled to make quality welds. In the custom shop it is more difficult to control these variables and in many cases it is not possible or practical to do so.

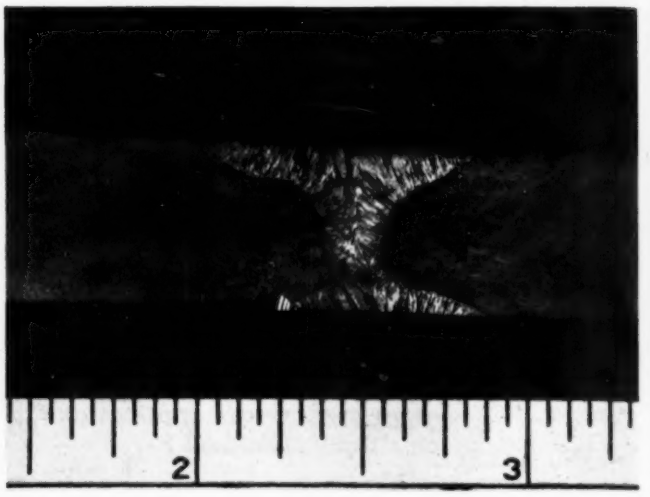

Fig. 4—Type 347 stainless-steel weld cross-section by inert-gas consumable electrode process.

It is a generally true statement, especially in the custom shop, for instance, that a one-pass weld will have some porosity such that a certain percentage of such welds will be "leakers", "seepers", or "weepers" when hydrostatic tested. A two-pass weld, however, will have less likelihood of porosity in each pass lining up such as to offer a leakage path. Such welds, consequently, have a much lower likelihood of leaking. Similarly, welds with three or more passes are less likely to show leakage.

It is true that the above is a general statement to which there are some exceptions. A fully controlled one-pass weld can be made tight to leakage tests which are sensitive enough to detect leakage of a few cubic centimeters in 100 years. Such welds must be made under extremely close control by highly competent technical supervision.

Generally, however, the custom shop prefers, where complete freedom from leakage is required not only on testing but also after service, a multipass weld. The tungsten-arc inert-gas process is particularly applicable in allowing multipass welds to be made in thin materials by virtue of allowing each pass to be a small one. Fig. 1 is a photograph of a cross-section of a three-pass butt weld in $^5/_8$-in. OD by 0.065 in. wall-type 304 stainless-

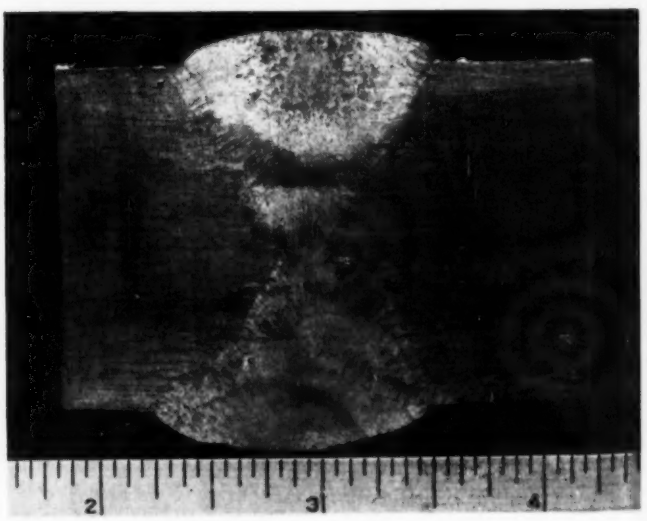

Fig. 5—Aluminum weld cross-section, made by inert-gas consumable electrode process.

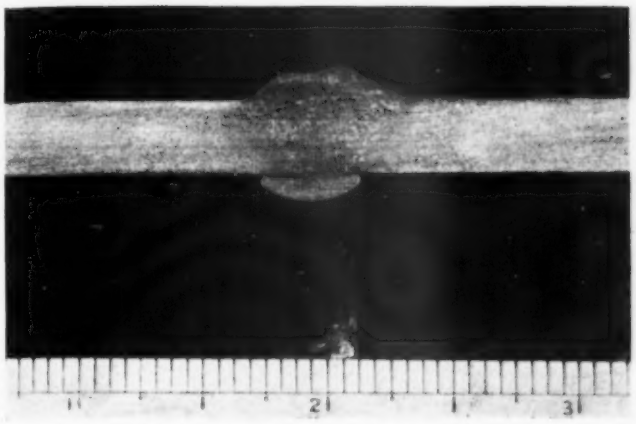

Fig. 6—Typical backing-strip type weld in carbon steel—manual metal-arc weld.

steel tube swaged and welded to a $^5/_8$-in. OD by 0.095 in. wall-type 304 stainless-steel tube. Filler rod was added to this weld by melting $^1/_{16}$-in. diameter bare rod of the proper analysis into the molten pool.

The same general reasoning holds true in welding a tube into a tube sheet. If leak tightness is dependent upon the weld alone and not from rolling tightly after welding, a multipass weld is much less likely to leak. On the other hand, in many cases, the weld is merely a seal weld rather than a strength weld and the one-pass seal weld can be repaired when it shows leakage and result in satisfactory service. Examples of each of these types of welds are shown in the photographs of Figs. 2 and 3. That shown in Fig. 2 is a multipass coated rod metallic arc weld and that in Fig. 3 is an inert gas weld, with the tube end furnishing the required filler rod.

Where diameters are sufficient for welding access inside and outside, the consumable electrode process allows welding of fairly heavy thickness materials with minimum weld groove machining by virtue of its deep penetration characteristics. Such a weld in type 347 austenitic stainless steel is shown in Fig. 4. This process is also particularly applicable to welding aluminum material—either single-pass welds which may be deposited very rapidly on thicknesses of $^1/_8$-in. or more, generally speaking, or multiple-pass welds for welding heavy aluminum. Fig. 5 shows a cross-section of a multiple-pass weld in aluminum.

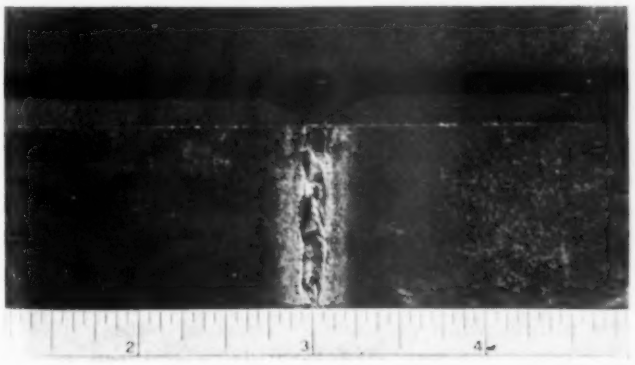

Fig. 7—Carbon steel material, manual inert-gas first-pass without ID atmosphere. Groove lips fused without filler metal. Shows as-welded appearance.

2. Welds without Backing Strips

For many years, circumferential welds in piping and tubing were made using backing strips against which the welds were deposited. These strips facilitated the obtaining of full thickness welds and minimized the danger of "burn throughs" and "icicles". They are now felt to be unsatisfactory for certain applications, however, because of their proneness to cause turbulence in some flow applications, because of crevices they present for entrapment of undesirable materials in some applications, and because of their proneness to have small root cracks at the notch of the weld-base material-backing strip junction. Fig. 6 shows a cross-section of a typical manual metal arc girth weld in carbon steel using a backing strip.

Although these welds with backing strips have been proven satisfactory for many applications, there is a

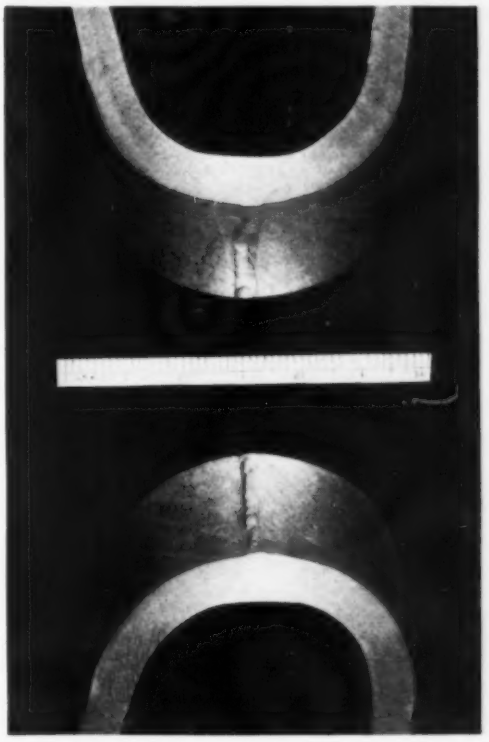

Fig. 8—Root bends, carbon steel, first pass welded as in Fig. 7, the balance welded by manual coated-rod process. Samples were cleaned in acid and bent with ID reinforcement left over.

strong general trend to eliminate their use. They can be eliminated and good welds obtained with various welding processes, if close tolerance machining of parts can be accomplished, if the welding operator is properly trained and conscientious, and if proper inspection procedures are instituted.

The oxyacetylene process is widely used for such type welds; the coated rod metal arc process is sometimes used; the tungsten arc inert gas process, however, is probably more readily usable for such joints in a large variety of materials, and requires least operator training generally speaking.

The techniques of making tungsten arc inert gas welds without a backing strip vary widely. Some techniques require the use of a filler rod which is held in one hand of

the operator, inserted under the arc, and melted as required. Or the materials themselves may be melted and serve in place of the filler rod for the first pass, at least. Some techniques require the separation of the

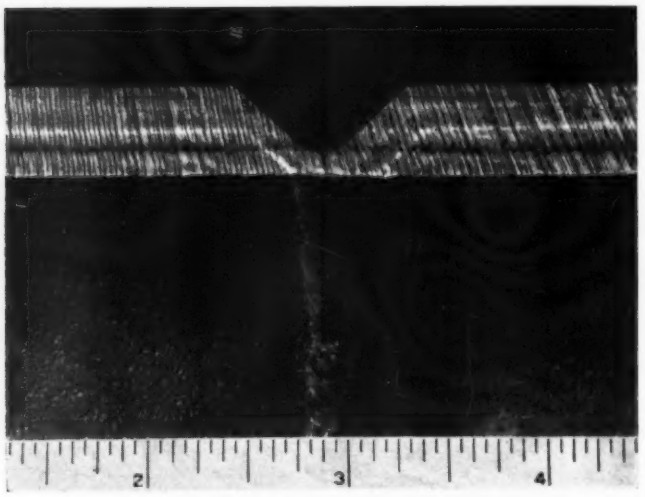

Fig. 9—Stainless Type 304 material, manual inert-gas welded, first pass with ID atmosphere. The groove lips were fused without filler metal. Appearance as welded.

root faces of the weld and others require the root faces to be held tightly together. Some techniques require the use of a controlled-pressure atmosphere inside during welding; others do not. Some techniques are applied by automatic or semi-automatic machines and some are entirely manual. Suffice it to say that entirely satis-

Fig. 10—Sample with first pass as shown in Fig. 9. Completed by manual metal-arc coated-rod welding. Sample bent with root-in tension with ID reinforcement left on.

factory welds can be obtained with all these various techniques.

The tungsten-arc inert-gas process is generally used for the first pass or first two passes of weld being made without a backing strip. The balance of the thickness can generally be more cheaply welded by using coated rod metal arc, submerged arc, or other processes.

Photographs of cross-sections of several circumferential joints using the manual tungsten-arc inert-gas process for the first pass are shown in Figs. 7 through 11. The weld shown in Fig. 1 was also made without a backing strip and was made using three passes of tungsten-arc inert-gas processes, the last two of which were with filler metal added.

Equipment is now available which will automatically hold a desired arc length and feed filler wire into the molten pool under the tungsten. In locations where access is sufficient, this equipment can automatically deposit a first pass or, in some cases, subsequent passes, either downhand or in any other position with very good results. Success depends upon close control of all variables but the variable of operator skill is minimized. Figs. 12 and 13 show cross-sections of welds made with this process in carbon steel and stainless steel.

General Operation Information

1. Electrical Equipment

Direct current, with straight or reverse polarity, may be used with most materials when tungsten-arc inert-gas

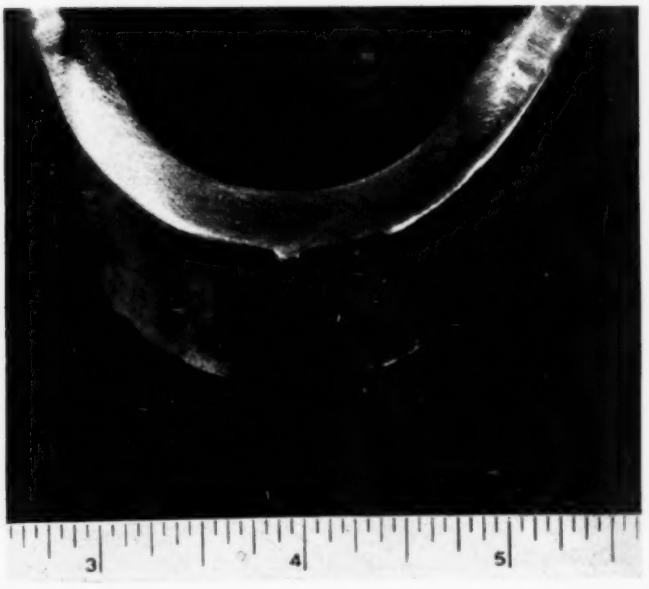

Fig. 11—Stainless-steel Type 304 identical to Figs. 9 and 10 except no ID atmosphere. Note resultant fuzzy appearance of ID reinforcement. Faster travel speed and minimum penetration improves appearance. This is a root-bend sample.

welding is employed. In some cases, however, notably with aluminum-tungsten arc welds, alternating current is required.

For consumable-electrode inert-gas welding, direct current supplied by a motor-generator or rectifier equipment is used. The latest electrical equipment of this type utilizes what is called a "constant potential" set. With this equipment, the rate of filler metal feed may be varied within fairly wide limits and current will automatically change so as to maintain a constant arc length, highly desirable for good welds.

Certain tungsten-arc applications require use of automatic arc-starting equipment. This may be "retract" starting, in which the electrode is moved to touch the work and then is automatically withdrawn to a specific arc length, or "high frequency" starting, in which a spark jumping the arc length ionizes a path through which the arc starts.

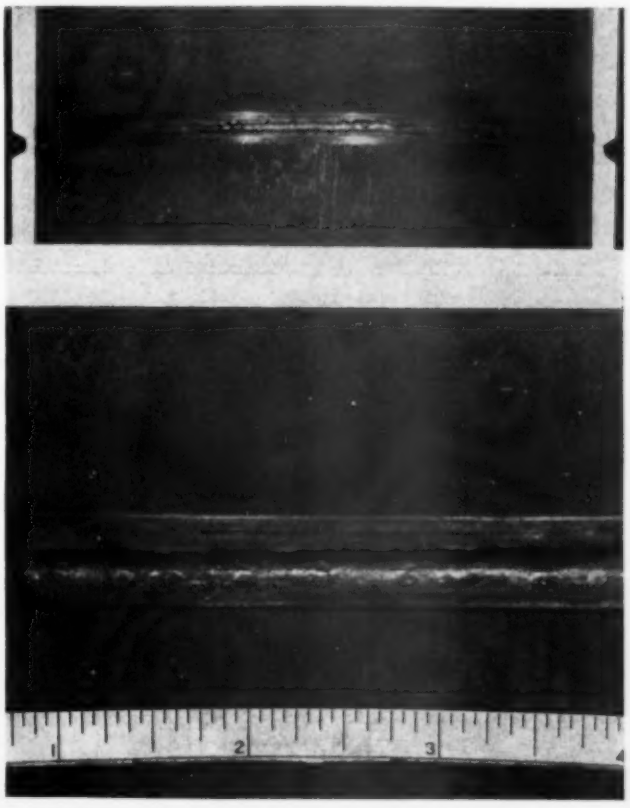

Fig. 12—Carbon steel first-pass welded with automatic tungsten-arc inert-gas with automatic filler-rod feed without ID atmosphere. Top shows half section of joint, bottom, closeup view of root weld.

Certain tungsten-arc applications also require the use of a "crater filler" attachment which gradually lowers welding current when stopping the arc.

Economics require other electrical equipment which will automatically start and stop flow of atmosphere gas and water as required.

2. Atmosphere Gases

Which gas to use is dependent upon conditions. Helium of high purity is an absolute necessity when welding certain materials such as nickel. In other cases helium of standard or lower purity may be used. In others argon must be used, and in still others a mixture of argon and helium may be used. Such a mixture is generally employed where argon gas is indicated but where a certain percentage of helium is not objectionable to the resultant product and is desirable because of being cheaper than argon.

In welding of carbon steels and some other materials, a gas of either helium or argon containing a small percentage of oxygen is desirable in some cases. In the interest of economy, considerable work is being done to determine whether cheaper atmosphere gases can be used. Development of such will greatly increase use of the subject welding process.

The atmosphere is generally introduced to the arc from a nozzle around the electrode, but in some cases the entire article being welded is surrounded with the atmosphere.

Precautions in Welding

1. Rimmed Steel

Carbon steels are usually welded with little difficulty, if deoxidized so as to be termed "fully killed" material, and if killed steel filler metal is used. "Rimmed" steels, however, welded without extra oxidation above that in the filler metal generally have excessive porosity in the weld. Generally, if the area to be welded is painted with an aluminum paint prior to each inert-arc pass, the resultant weld will be much sounder.

2. Austenitic Stainless Steel

Welds in stainless steels must be closely controlled to eliminate microfissures. Generally speaking, these defects are present in the weld if the weld is fully austenitic. If, however, the weld is balanced in analysis so as to have a few per cent of delta ferrite, no microfissures occur. In order to obtain such an analysis balance, proper cognizance must be taken of base metal analysis, filler metal analysis, and dilution of the two.

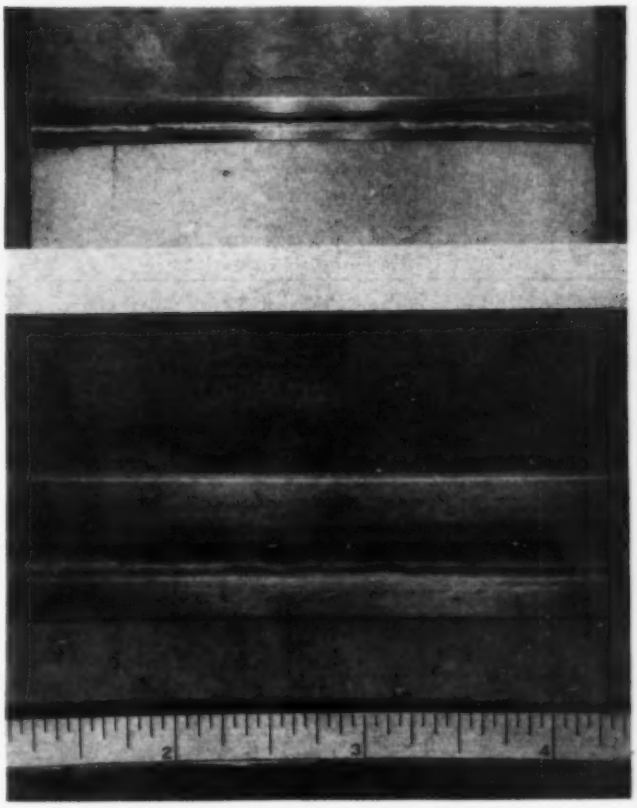

Fig. 13—Type 304 stainless steel first pass welded with automatic tungsten arc inert-gas with automatic filler-rod feed and ID atmosphere. Top view shows half section of joint; bottom a closeup view of root weld.

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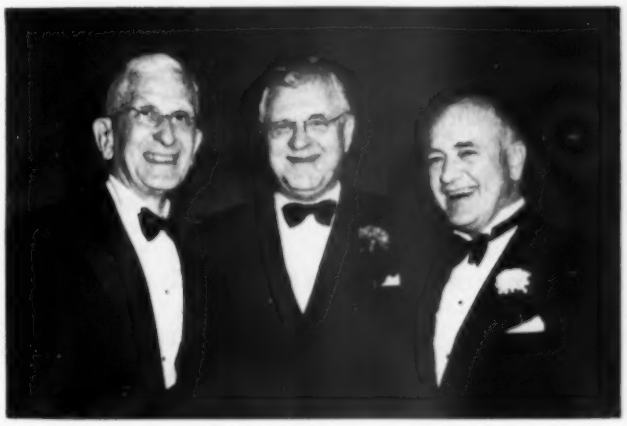
ASME Annual Meeting Highlights

THE 74th Annual Meeting of The American Society of Mechanical Engineers was held at the Hotels Statler, McAlpin and Governor Clinton in New York City from November 29 to December 4. More than 6000 engineers were present for the record-size program comprising some 300 technical papers and over 100 separate sessions. Highlights of the unusually diverse program included a symposium on outdoor boiler plants, a session on manpower requirements in central stations, several papers relating to controlled-circulation boilers, a panel discussion on residual fuel oil, and a progress report on industrial atomic power.

Lewis K. Sillcox of The New York Air Brake Company was elected president of the Society, succeeding Frederick Blackall, jr., of The Taft-Peirce Manufacturing Co.



L. K. Sillcox, incoming president; C. E. Davies, secretary of ASME; F. S. Blackall, jr., retiring president

Regional vice presidents elected included W. F. Thompson of Westcott & Mapes, Inc.; Prof. William G. McLean of Lafayette College; Thompson Chandler of Carbide & Carbon Chemical Co.; Vernon A. Peterson of the Elliott Company, and Prof. Clifford H. Shumaker of Southern Methodist University. Frank L. Bradley of Forstmann Woolen Co. and Robert B. Lea of the Sperry Corporation were elected directors-at-large.

Principal speaker at the annual banquet was Gwilym Price, president of Westinghouse Electric Corp., who urged engineers to play a greater rôle in public life and to take the lead in applying engineering principles to social problems. He added that it might be possible for the engineer to erect a bridge between the technical and humanistic world and bring diverse groups together into a common program such as no one else is capable of doing.

Awards were presented to a number of industrialists and educators at the banquet. Crosby Field, president of the Flakice Corporation, received the ASME medal; A. G. Christie, professor emeritus of mechanical engineering at Johns Hopkins University, the first ASME-George Westinghouse gold medal award; W. H. McAdams, professor of chemical engineering at Massachusetts Institute of Technology, the Warner medal; J. C. Falkner, Consolidated Edison Co. of New York, the Melville medal for papers on central-station quick starts.

Honorary membership in the Society was conferred on William A. Hanley, a retired vice president of Eli Lilly and Co.; William F. Ryan, vice president of Stone & Webster Engineering Corp.; Admiral Edward L. Cochrane, dean of engineering at Massachusetts Institute of Technology; Sheppard T. Powell, consulting engineer of Baltimore; and A. C. Monteith, vice president in charge of engineering of Westinghouse Electric Corp.

From left to right; W. A. Hanley, W. F. Ryan, E. L. Cochrane, S. T. Powell, and A. C. Monteith

Outdoor Power Stations

A highly important and very well attended session was conducted on design and experience with outdoor power plants. It numbered five principals in the symposium plus several who presented prepared discussions. **V. F. Estcourt,** Pacific Gas & Electric Co. opened the session with a paper forwarded from Lausanne, Switzerland, by **Louis Elliott,** Ebasco Services. This paper traced the evolution of the outdoor power plant from the earliest outdoor substation transformer and high-voltage switching equipment through to today where the author's company, alone, can count 164 steam generators, 155 turbine-generators in 70 stations performing under essentially outdoor conditions. Mr. Elliott felt outdoor plants are functional, satisfactory, practicable, moderate in cost and reliable in performance.

Walter F. Friend, Ebasco Services, furthered the general background on outdoor plants by discussing how these plants have adapted themselves to their special environments. But he made particular emphasis of the point that along with the progressive reduction of housing there have been considerable concurrent simplifications. The principal simplifications he cited were unit boiler and turbine arrangements, a major reduction in cross connections and spares, low headroom designs for condensers, centralized controls that are combined for boiler and turbine, plant foundations using slabs at grade level and wall constructions of light weight types, without masonry.

These simplifications steps afforded considerable flexibility and permitted a number of combinations to

meet varying topography limitations, climate peculiarities, special community characteristics, economic factors and even rather individual preferences of executives and operators. Obviously topography and climate can and do exert very special influences on equipment selection as well as maintenance practices for outdoor plants. But, oddly enough, Mr. Friend reported that Ebasco now seldom estimated savings for outdoor as against conventional power plants but rather made arbitrary assumptions for alternate housed plant designs.

E. C. Duffy, Long Island Lighting Co., indicated that his company, since its Port Jefferson installation in 1946, has been increasingly moving toward more outdoor construction. Each step has been carefully reviewed and its merits weighed before furthering outdoor designs.

Mr. Duffy believed the early experiences of his company clearly demonstrated a saving of about $4.00 per kw over conventional station designs and with greater personnel comfort for eight to ten months of each year without any penalties in costs or reliability of operation. A very strong highlight of Mr. Duffy's comments was one tabulation showing the overall savings his company realized by increasing the scope of outdoor design, power station by power station, and the savings effected thereby.

In summation Mr Duffy went on record that in Long Island Lighting Co.'s opinion after five years of experience, semi-outdoor boilers are practical, and here to stay. Further the company believes an outdoor turbine will be similarly regarded.

C. F. Gaffert, Sargent & Lundy, took a somewhat different view of the major equipment. The outdoor boiler, Mr. Gaffert maintained, is firmly established but it is still a definitely open question as to whether the outdoor turbine saves any appreciable investment. An enclosed central control room with adequate glazing for outdoor boiler and turbine plants, though, would give, in Mr. Gaffert's opinion, not only weather protection and improved vision for operators but would reduce operating manpower. The twenty-five station units Sargent & Lundy have either installed or under design prompted the author's belief that the outdoor plant has its place particularly where climate is not too extreme.

F. W. Argue, Stone & Webster Engineering Corp., approached the subject of outdoor stations from a different angle. In his opinion the exact extent of enclosure for any station must be worked out on the basis of its effect on reliability, availability and maintenance expense. And the only true gage of this effect is the operating experience the various power stations accumulate. The author expressed the hope that this information will continue to be made available so that many of the factors now regarded as intangible can be more properly fitted into design thinking.

Mr. Argue developed a set of estimates of construction costs for two designs of stations. These estimates were based on three primary design criteria, namely, outdoor construction, minimum enclosed construction, and conventional enclosure. This last he subdivided to take into account complete housing for a mild climate where uninsulated walls would be satisfactory and for a more severe climate requiring insulated wall construction.

A set of bar charts was presented to graphically show the differences in costs for the three design criteria Mr. Argue established. These charts compared totals for completed stations as well as unit breakdowns such as boiler room costs or those for turbine and control rooms.

Discussion

Over and above the principal papers mentioned above were several important prepared discussions featuring experience reports from **J. W. Keck,** Florida Power & Light Co., **C. W. Geue,** Texas Electric Service Co., **Harry G. Hiebeler,** Houston Lighting and Power Co., **W. L. Chadwick,** Southern California Edison Co., **C. C. Whelchel,** Pacific Gas & Electric Co., **E. C. Gaston,** Southern Services, Inc., **M. K. Drewry,** Wisconsin Electric Power Co. and **J. A. Inwright,** Public Service Electric and Gas Co. plus digests of invited comments from turbine, boiler, control equipment, and piping manufacturers.

The comments of E. C. Gaston and **W. A. Pollock,** Wisconsin Electric Power Co., substituting for M. K. Drewry, were of special note since both men from widely separated sections of the country found that they had successfully met the objectives of outdoor station design, greatly reduced building costs, by going to less expensive materials and elimination of ornamental features. They further felt that there were operating and especially maintenance advantages in enclosed power stations.

Controlled Circulation Featured

Outstanding among the sessions was that which comprised three papers on controlled circulation. The special interest in this subject, as attested by the large attendance, is attributable to the widespread acceptance of this type of boiler for large high-pressure units by the electric utilities. Three papers were presented. The first, by **W. H. Armacost,** vice president of Combustion Engineering, Inc., dealt basically with controlled circulation, reviewed its development and described designs. The second paper, under joint authorship of **T. E. Crossan** superintendent of production for the Virginia Electric & Power Co., and **W. F. Ryan,** vice president and engineering manager of Stone & Webster Engineering Corp., dealt with the installation at the Chesterfield Generating Station, covering the economics, experience and performance. The third paper by **F. P. Fairchild,** chief engineer, Electric Generating Department of the Public Service Electric & Gas Co., described the new Kearny Generating Station of that company with particular reference to its controlled circulation units.

Mr. Armacost pointed out that the fundamental difference between natural and controlled circulation units lies in the employment of pumps to force the water through the evaporative section with orifices to control its distribution and the employment of small diameter thin-walled tubes (1 to $1^5/_8$ in.) with their accompanying lower hot-face temperature and lower thermal stresses which make them especially adaptable to high pressures and high temperatures. Such units are flexible in arrangement, responsive to load demands and insure a steady water level on quick load swings.

Experiences with the pioneer installation at Somerset Station of the Montaup Electric Co. in 1942 were reviewed and subsequent developments traced, many of the

improvements being incorporated in the first postwar controlled-circulation unit at Chesterfield.

The unit recently put into service at Kearny Station is typical of current installations of controlled-circulation boilers. It has a continuous capacity of 955,000 lb of steam per hour at 2650 psi design pressure with primary steam temperature of 1100 F and 1050 F reheat. Its special features include improved circulation pumps and the latest drum internals for steam purification; the substitution of distribution drums at the bottom of the unit in place of the previously used headers and strainers; suspension of the circulating pumps from the downtake header, with discharge from all three pumps connected to a common discharge header; and panel construction for furnace walls to eliminate steel casing for pressurized furnaces and insure a gas-tight setting for suction firing.

Other installations that Mr. Armacost briefly summarized were the Etiwanda Station of the Southern California Edison Co. with two 920,000-lb per hr, 2100-psi, 1000/1000-F units; the Oak Creek Station of Wisconsin Electric Power Co. with one 795,000-lb per hr, 1775-psi and one 2025-psi unit, both designed for 1004-F primary and 1000-F reheat steam temperatures; the Buck Station of Duke Power Co. with two 900,000-lb per hr, 2030-psi, 1000/1000-F units; Eastlake Station of Cleveland Electric Illuminating Co. with three 875,000-lb per hr units at 2030 psi, 1050/1000-F steam temperature, and the Cromby Station of Philadelphia Electric Co. which will initially contain one 1,450,000-lb per hr, 2075-psi, 1000/1000-F unit employing two separate furnaces, one arranged for control of primary steam temperature and the other reheat. These furnaces have independent tilting-burner controls.

In addition to the foregoing there are numerous others now in either the design or installation stages.

Controlled Circulation at Chesterfield

Messrs. Crossan and Ryan pointed out that the Chesterfield Station represents a strictly utilitarian design. The first section, started during World War II, was laid out to economize on materials, particularly steel. Hence the walls were of uninsulated corrugated asbestos with wooden sashes and wooden girts employed for mounting the first unit. Tiled walls and floors were omitted and preferred standard turbines have been employed. Despite steam conditions of 850 psig and 900 F for the first two units, the station heat rate ranked among the lowest 15 per cent reported by the Federal Power Commission in its annual study of plant and production costs.

The latest extension to Chesterfield employs a controlled-circulation boiler rated at 750,000 lb per hr at 1500 psig, 1000/1000 F, supplying a 100,000-kw turbine-generator. This went into commercial operation December 1, 1952. Since that date there have been two outages, one forced and one scheduled. The former occurred when a normally latched-in relay, which trips the fires in case of low boiler circulating pump differential, was accidentally de-energized by an electrician. The latter was to remove fine-mesh strainers from the turbine, stop and intercept valves and to complete certain construction items. As of September 3 the unit had been in continuous operation since February 4, and availability since first being placed in service on December 1, 1952, has been 98.5 per cent.

During most of the hours of pump operation, sealing of the pumps was accomplished by injecting water at a pressure slightly above the circulating pump pressure, for which about 20 gpm per pump is required. The maximum time for which mechanical seals have thus far been fully effective has been about 2000 hr. However, a mechanical seal failure is not sudden and does not limit boiler operation as a switch to sealing water is made and the pump continues in operation.

The authors mentioned that the controlled circulation design was selected for the last unit at Chesterfield, as well as for two later units at Portsmouth Station and one at Possum Point in order to achieve the maximum return on the investment.

Rear elevation of the boiler plant building, showing the greater capacity of the controlled-circulation unit in less space at Chesterfield

New Kearny Generating Station

Mr. Fairchild described the more important design features of the new Kearny Station and pointed out significant differences between that and the Sewaren Station of his company. At Kearny the operating pressure at the superheater outlet is 2350 psig, 1100 F initial steam temperature and 1050 F reheat. The two controlled-circulation boilers, each of which serves a 145,000-kw turbine-generator, employ pressurized firing, gas recirculation and divided furnaces of the continuous-discharge, wet-bottom type. The dividing wall between the two halves of the furnace has large openings to equalize furnace pressure. The furnace wall panels of $1^1/_2$ and $1^5/_8$-in. tubes range in width from 15 to 24 tubes and in lengths from 24 to 49 ft and were shop-assembled and shipped to the plant. These insured gas-leak tightness for pressurized firing and minimized field welding.

The turbine-generators are of the tandem-compound, 3600-rpm type having a high-pressure section, a single-flow reheat section and a triple-flow, low-pressure section. Side exhausts to the twin condensers at the lower half of the low-pressure element make it possible to place the operating floor only 15 ft above the ground floor. Each turbine drives two generators in tandem. Centralized control is provided in a soundproof air-conditioned room.

In view of the high steam temperature of 1100 F the entire main steam system, from the superheater-outlet header to the first-stage nozzle of the turbine is of austenitic stainless steel, chromium-nickel-columbium stabilized. This includes the main steam piping, turbine stop valves, control valve chests, and a section of the inner high-pressure turbine shell. The superheater materials, starting from the primary end, are carbon-molybdenum steel, chromium-silicon-molybdenum steel and chromium-nickel-titanium stabilized steel. The main steam piping was made by forging and boring. The hot reheat piping is of $2^1/_4$ per cent chromium, 1 per cent molybdenum steel rolled from plate and welded.

Turbine-Generator Papers

Among the papers dealing with steam turbines was one on "The Economics of Large Reheat Turbine Exhaust End Size Selection" by **D. W. R. Morgan, Jr.,** and **S. D. Fulton,** both of Westinghouse Electric Corp.; another on "Reheat Turbines at Chesterfield and Kearny Stations," by **C. W. Elston** of General Electric Co.; "Testing Large Steam Turbines With Weighing Tanks," by **W. A. Pollock** of Wisconsin Electric Power Co.; "A Short Method for Evaluation of the Effect of Some Terminal Cycle Variations on Steam Turbine Heat Rates," by **S. D. Fulton;** and "Notes on Development of Turbine-Generator Sets for Shipboard Service," by **A. G. Gale** and **H. J. Chase,** of General Electric Co.

The first of these papers offered a method for making a study of capability performance of large reheat turbine exhaust-end size, and of other plant components affected by heat rejected to the condenser. Although the heat rate in Btu per kilowatt-hour is a function of the exhaust stage annulus area, such variable factors as condensing-water temperature, fuel costs, load factor, interest charges, etc., prevent there being any single proper exhaust size for a given turbine capability.

The method proposed is based on the assumption that the exhaust flow for two turbine-generator units, having different exhaust-end annuli but designed for the same capability, steam conditions and feed-heating cycle, is the same when operating at the same throttle flow. Therefore, the difference in exhaust loss (in kilowatts) is the difference in kilowatts at the generator terminals, if the generator efficiency and difference in mechanical losses are disregarded. The exhaust flows can be determined from heat balance calculations or approximated from the turbine heat rate, and exhaust loss difference curves, plotted as a function of exhaust flow, provide a ready means of determining the exhaust loss difference in kilowatts between turbines of different exhaust annulus areas. Application of this method was worked out in detail with the assistance of a number of charts.

The authors presented a table of exhaust end-capability combinations for reheat turbines of both the tandem and cross-compound types, as representing the practice of their company. A second table gave the approximate condenser duty, in Btu per pound of exhaust flow for incremental initial pressures from 1250 to 2400 psig and both initial and reheat temperatures from 950 to 1050 F, with exhaust pressures of 1, 1.5 and 2 in. Hg. Still another table gave approximate boiler feed pump power, in per cent of kilowatt output for throttle pressures of 1250 to 2400 psi. This ranged from 1.3 to 2.5 per cent.

In the second paper Mr. Elston described features of unit No. 3 at the Chesterfield Station of Virginia Electric and Power Co. and units No. 7 and No. 8 at Kearny Station of Public Service Electric and Gas Co. The former is a typical 90,000-kw ASME-AIEE Preferred Standard 3600-rpm reheat unit with a maximum rating of 99,000 kw and designed for 1450-psig, 1000-F initial steam conditions, 1000-F reheat temperature and $1^1/_2$-in. exhaust pressure. The latter two are 145,000-kw (maximum rating) 3600-rpm tandem-compound triple-flow reheat turbines designed for 2350-psig, 1100-F initial steam conditions, 1050-F reheat and $1^1/_2$-in. exhaust pressure.

The Chesterfield unit is a typical opposed-flow tandem-compound double-flow turbine, of which 34 are in operation. The opposed-flow arrangement of the high- and intermediate-pressure sections with the initial and reheat steam inlets adjacent to each other confines the high temperatures in a single, relatively short portion of the turbine and essentially eliminates temperature gradients across the thick wall portions of the high-pressure inner casing.

The Kearny units represent a more advanced design for higher steam conditions and larger rating. The same opposed-flow principle is used, except that an external control valve chest is utilized because of the necessity of using austenitic steel at 1100 F. Because of the 1050-F reheat temperature double-shell construction is used at the reheat point as well as the main steam inlet. After expanding through the first three stages following reheat admission, the steam passes to two intercept valves and then expands through seven single-flow stages to the triple-flow low-pressure section. Approximately one-third the flow expands through the single-flow portion of this section and the remainder through an internal crossover passage to the double-flow portion.

The paper by Mr. Pollock emphasized the advantages of measuring steam flow to a turbine by means of condensate weighing tanks. With a background of forty-three years favorable experience with this method of measurement, the Wisconsin Electric Power Co. installed scale tanks in its new Oak Creek Power Plant to permit testing the 120,000-kw cross-compound reheat turbines. These tanks were installed at a total cost of less than ten cents per kilowatt of turbine capacity. Besides permitting accurate testing of the turbines and their auxiliaries they provide for storage of cold condensate. The installation was described in detail as well as the method employed for calibration.

In support of the tank weighing method, the author stated that a 1 per cent greater accuracy, compared with condensate-flow meters and 1.25 per cent over steam-flow meters, as shown by comparative tests at Port Washington Station, resulted in a 1 per cent better guaranteed turbine heat rate for Oak Creek, and that this justified a capital expenditure of $300,000, or $2.50 per kw.

The cost of conducting a weighed water test for a period of 98 hr was given as less than $350.

Steam station performance or betterment engineers have long recognized a need for a quick, accurate method of determining the effect minor changes in the steam turbine cycle exert on heat rate. The paper by Mr. Fulton not only outlined such a method, but pointed the way to get sufficiently accurate results with only slide-rule calculations.

The author built his method around the fundamental definition of gross heat rate as being the heat energy input to the turbine divided by kilowatt output at the generator terminals. Any change in kilowatt output or heat energy input immediately affects heat rate. And by confining calculations to these differences, the need for a complete set of heater calculations is avoided. The author derived equations for ten basic considerations that could affect turbine heat rate: (1) change in distribution of liquid enthalpy rise between two adjacent heaters; (2) change in pressure drop of extracted steam; (3) change in heater-terminal difference; (4) change in drain-cooler approach; (5) effect of compressibility on liquid enthalpy; (6) inclusion or omission of evaporative condenser; (7) changes in liquid enthalpy of boiler feedwater from an external heat source; (8) change in final feedwater enthalpy; (9) inclusion or omission of an evaporator; and (10) change from a flashed or drain-cooler heater to a contact or pumped heater or vice versa.

The paper by Messrs. Gale and Chase reviewed some of the problems encountered in designing turbine-generator sets for marine service and presented some typical arrangements to illustrate the present trend toward producing a unit of minimum size and weight.

Marine installations must take into account the rolling and pitching of the ship in a seaway as well as the weaving and distortion of the hull structure as a foundation. The first mentioned consideration makes it necessary that all oil-drain lines from bearings be sloped to allow for list or trim, and the last mentioned may adversely affect gear-tooth contact in a geared unit as well as distribution of load on bearings.

The most common arrangement of elements for a shipboard turbine-generator set to serve a 3-phase, 60-cycle, 450-hp system consists of a relatively high-speed turbine driving a 1200-rpm generator through a single-reduction gear. It is common practice to supply steam to such turbine-generator sets from the same boilers and at the same steam conditions as the main propulsion unit. The small high-speed turbines are adapted to deliver good steam rates.

Modern marine practice favors alternating current for the generating plant and distribution system, with conversion to direct current at certain locations, such as cargo winches, where speed control of the motors is necessary. Future developments must take into account the need for higher ratings for generator units provide for increasing use of electric power aboard ships.

Stationary and Marine Power Practice Compared

An extensive paper covering 70 pages under the authorship of **Mark L. Ireland, Jr.**, of Newport News Shipbuilding and Drydock Co. and **Frank A. Ritchings** and **Sabin Crocker**, of Ebasco Services, Inc., dealt in detail with a comparison of land and marine steam-power-plant practice, this being confined to installations of comparable capacity, excluding large utility plants. That is, steam capacities of 50,000 to 100,000 lb per hr for marine boilers and 100,000–200,000 for land boilers.

While there do not appear to be any outstanding basic differences in the two fields, such differences as exist are dictated largely by space limitations aboard ship, the general use of steam auxiliary drives, employment of two boilers per turbine, a difference in availability requirements, higher heat releases afloat and freedom to employ turbine speeds above the 3600-rpm synchronous speed of utility machines.

The size of a marine power plant is largely a function of the ship's speed and varies from the third to fifth power of the speed. Moreover, the economic problems vary with different types of ships. For example, higher investment in equipment to secure better fuel rates is justifiable for long-haul tankers as the saving in fuel space permits larger oil-carrying capacity with consequent greater earnings; whereas ordinary cargo ships that discharge at several ports do not continuously carry a full cargo.

The concept of availability is quite different as between stationary and marine power plants. Whereas the former, especially those of unit design, must consider the availability of all major equipment on a 24-hr yearly basis, with the latter an important factor is the scheduled periods in port for cargo handling at which time maintenance and minor repairs can be given attention. Furthermore, it is usual with cargo vessels to allow 25 days a year for annual ship overhaul at which time any major work can be done on the power plant. An exception exists in the case of tankers that ordinarily spend only 16 to 18 hr in port between trips.

As to steam conditions, 400 psi, 750 F was first employed in the marine field in 1930, and in 1939 the Maritime Commission's construction program standardized on 450 psig and 750 F although a turbine-electric drive tanker employed 625 psig, 835 F in 1938, followed by another in 1940 with 625 psig, 920 F. The P-2 Class of

Maritime Commission vessels later employed 600 psig, 825 F and postwar practice has largely followed Navy conditions of 600 psig, 850 F. Exceptions were some supertankers of 1948 which employed 850 psig, 850 F and 650 psig, 1020 F in 1950. Other exceptions were some cargo vessels built for 1200 psig, 750 F initial and 750 F reheat, and ore carriers with 1450 psig, 750 F with two stages of steam-to-steam reheat.

The design of marine boilers is influenced by both space and weight considerations. They usually burn oil, have smaller furnaces and employ higher rates of heat release than land boilers which are now more generally designed to burn pulverized coal, oil or gas. Also, double casings are common with marine boilers which in U. S. practice has permitted avoiding use of induced-draft fans.

Marine power plants are somewhat handicapped by reversing requirements which add to the length of the low-pressure turbine shaft. Quick starting and maneuvering of marine turbines is comparable with quick starting and load swings in stationary plants.

The manpower situations in the two fields are not comparable. On land the unit arrangement and centralized control has made for reduction in operating personnel, whereas on ships that make long voyages the power plant crew must spend considerable time on maintenance, although such work is usually done by shore personnel on ships that spend relatively long periods in port between voyages. Passenger vessels require a larger engineer force because of the large amount of services requiring attention.

Session on Atomic Energy

The papers at this session covered four broad categories, namely, technical, economic, legal and policy. That by **C. C. Whelchel** of Pacific Gas & Electric Co. was confined to a consideration of the economic aspects, based (1) on present knowledge, with certain assumptions, and (2) on factors that may assume importance if nuclear power becomes competitive with that produced by conventional steam stations. The economic peacetime role of nuclear energy is seen first as central station power with possible later extensions to the field of transportation; also, the application of radioactive isotopes in research, medicine and industry.

The nuclear power plant is presently conceived as consisting of a reactor source, a heat-exchanger and a steam turbine-generator. When an atom fissions, heat is generated, fission products are created and neutrons are released. The neutrons maintain the chain reaction and create by-product plutonium which, as well as the fission products, represents a possible source of revenue for the industrial reactor. However, at present the fission products are a liability rather than a source of revenue, but they are likely to be used as a radiation tool in research and industry.

Although plutonium in the dual-purpose plant is a co-product of military value, the author pointed out that in the single-purpose nuclear power plant the plutonium by-product would be of material value in supplementing the fuel supply of U-235. He offered an economic comparison of costs associated with the conventional steam plant and corresponding costs that must be realized in order for the nuclear plants to break even with steam.

Today's estimates of capital costs for nuclear power plants vary greatly, and range from $350 to $900 per kilowatt of capacity for large plants. Therefore, to be competitive, even under conditions of favorable nuclear fuel costs, capital costs must be lowered to something like $200 to $300 per kilowatt. In view of probable high reactor costs, Mr. Whelchel expressed the opinion that the cost of nuclear fuel must come down to the order of 0 to 1.3 mills per kilowatt-hour. He pointed out, furthermore, that since the cost of generating power is only about 25 per cent of the domestic utility bill, nuclear power does not necessarily promise cheap power. The real advancements, in his opinion, must come from continued research and designs that hold promise of lowering both capital and operating costs.

In the technical category **John W. Landis** of The Babcock & Wilcox Co. presented a list of some of the major problems which face the nuclear-power-reactor designer today:

1. Achieving greater burnout of both natural and enriched fuels, thus reducing the frequency or rate of chemical processing.
2. Reducing the complexity and cost of chemical processing.
3. Reducing or eliminating expensive fuel-element fabrication.
4. Eliminating external heat exchange by boiling in the reactor core.
5. Attaining high specific power.
6. Reducing corrosion caused by coolants and/or liquid fuels.
7. Designing inexpensive leakproof equipment to handle liquid metal coolants.
8. Improving methods of breeding, both internal and external.
9. Working out better control devices.
10. Developing materials of construction which do not absorb neutrons parasitically, and which can withstand high temperatures and intense and prolonged neutron bombardment.
11. Reducing the costs of special materials such as zirconium, beryllium, heavy water and titanium.

E. Blythe Stason, dean of the law school at the University of Michigan, discussed some of the legal and policy problems connected with the development of nuclear power by private industry. He pointed out that under the Atomic Energy Act of 1946 the foundation of ownership of both facilities and fissionable fuel is lacking. This is also the case with private acquisition of source materials, such as uranium and thorium ores, and with the right of continuity in business. Under the present law the Atomic Energy Commission may terminate licensing agreements at any time, without notice or opportunity for hearing and without showing of cause. Until these serious legal barriers are removed by Congressional action, private nuclear electric power operations are virtually precluded.

Another barrier is that private patents in the usual sense are not permitted. No patents can be obtained for inventions solely useful for weapons or for the production of fissionable material, only the latter being an objection from the point of view of private power genera-

tion. In addition, there is a provision in the Atomic Energy Act which permits the Atomic Energy Commission to declare patents to be "affected with the public interest."

Other Federal legal problems mentioned by Dean Stason included those relating to navigable stream pollution, antitrust laws, and the Public Utility Holding Company Act. Certain problems may also arise from state laws, particularly in connection with obtaining certificates of convenience and necessity and in establishing rate schedules and assuring adequate safety protection. Local legal problems may arise from the existence of zoning laws and building regulations.

Discussion

Much of the discussion centered around the question of what would happen if a reactor should go out of control. It was pointed out that reactors are not capable of exploding in the usual sense of the term but can overheat and melt down, which may release fission products. For self-regulating reactors large exclusion areas may not be necessary, particularly since experience has demonstrated that reactor operation is much safer than was believed to be the case a few years ago. Mention was made of the danger of state regulatory bodies getting into the picture too soon and freezing safety regulations into law that might unnecessarily restrict nuclear-reactor designers.

In response to a question concerning the ability of nuclear reactors to respond to major load changes, the statement was made that the inertia of a reactor is comparable to a conventional boiler and that no difficulty was anticipated in this respect in meeting changing power demands.

Fuels Luncheon

Addressing the Fuels Luncheon on "Power Today and Tomorrow," **Alfred Iddles,** president of Babcock & Wilcox Co., traced power development from the middle of the last century with its belt drives from very low-pressure reciprocating engines; through the era of the first central stations operating at around 120 psi, then to the pre-World War I period of 350 psi, 700 F, with pressures reaching 600 psi in 1924; 1200 psi, 750 F in 1929; and finally 2650 psi in 1938 in one installation (Twin Branch).

About 80 per cent of the recent units employ reheat, he said, and 2000 to 2300 psi is becoming popular for central stations. Two stages of reheat are now in the offing, with one such installation now under construction.

With 3200 psi the upper limit for natural circulation, Mr. Iddles saw as the next step the employment of supercritical pressures with forced circulation, citing the 4500-psi topping installation of Philo which is now being designed. This should produce a kilowatt-hour on about 8500 Btu, and for still better economy he suggested 8000 or 10000 psi with 1200 F as soon as the necessary materials become available.

The mercury-steam cycle which once held much promise had not been too successful and is now practically useless when compared with later steam cycle progress.

The gas-steam turbine combination may have possibilities as a means of securing further thermal economy; and unit sizes may increase still further, but with decreasing savings due to size alone.

Mr. Iddles expressed the opinion that too much has been claimed for the possibilities of atomic energy. If developed commercially, he believed its widest application would be in areas where cheap coal or other fuel is not available, but he refused to offer any predictions.

In conclusion, he attributed progress in power development over the years to the non-conformists in that field.

Underground Gasification

A report on cooperative field-scale experiments was presented by **M. H. Fies** of the Alabama Power Co. and **J. L. Elder** of the U. S. Bureau of Mines in a paper entitled "Underground Gasification of Coal at Gorgas, Alabama." These experiments were begun in 1946 to develop a low-cost process for the recovery of either the chemical constituents or the energy of coal in forms suitable either for the synthesis of liquid fuels and organic chemicals or for the production of power. From 1946 to 1951 the experiments featured "stream-type" operation in which a passage was prepared by mining methods and a stream of air or other gas-making fluid was swept along an incandescent coal-coke face.

In 1951 and 1952 field-scale experiments were conducted by a method known as electrolinking carbonization, which permits establishing a passage through a coal bed without mining. If electrodes are placed at two points in a coal bed and a potential is applied, some of the current will be passed through the coal, generating heat and changing the structure of the carbon. After a time coke is formed and a good electrical path is established. The continued use of electric current results in carbonization of quantities of coal, accompanied by evolution of gas, tar and other products. A bed of hot, cracked and carbonaceous material is formed, and air or other gas-making fluids may be passed through it.

In gasification with air a lean producer gas is made which can be used at the point where produced in generating electric power, possibly by means of gas-turbine installations. Substitution of oxygen for air results in the production of nitrogen-free and improved-quality gas, although the results of only one gasification test with oxygen are available. Alternate gasification with air followed by steam runs provides an improved-quality product at a minimum cost.

Ash Handling

Air and water pollution represent two major problems according to **L. E. Mylting** of the Allen-Sherman-Hoff Co. in a paper entitled "Economics of Ash Handling." Air pollution is of principal concern in systems handling bottom ash and fly ash in the dry state. All conveying air must be properly cleaned before it is returned to the atmosphere. Final loading and disposal must be planned to eliminate any chance of dust entering the atmosphere.

To avoid stream and lake pollution several methods of water recirculation have been devised. Where fill areas are available provisions are made for settling in large ponds. The less water used the less difficult is the problem of preventing pollution, and the more economical the installation.

Mr. Mylting mentioned the component requirements for handling bottom ash and fly ash. He urged that capital investments and operating costs be considered completely in order to develop an optimum design. The costs of potential outages must be carefully considered in an economic evaluation of ash-handling equipment.

Spreader-Stoker Firing

In a paper entitled "Boiler and Furnace Designed for Spreader-Stoker Firing" **L. H. Coykendall** and **P. R. Loughin** of the Babcock & Wilcox Co. reviewed briefly some of the history of the spreader-stoker firing and described the development of a furnace and boiler design adapted specially for the spreader stoker. Among the conclusions based upon a survey conducted in 1947 were the following:

1. The furnace walls should be water cooled but not more than required to prevent excessive maintenance and troublesome slagging.
2. Furnace arrangement should be such as to promote maximum turbulence and to provide for the proper flow of furnace gases.
3. The distance from the grate to the lowest point of the furnace outlet should be in the order of 12 ft or more.
4. Gas turns and baffles that concentrate flue dust should be eliminated from the boiler bank to avoid erosion of pressure parts.
5. Large hoppers are recommended in order to reduce dust loading and collect for reinjection the most abrasive large particles high in carbon content.

The authors described a standardized design developed in 1949 following two years of investigation, study and planning. They provided detailed information on flue-dust distribution in a test installation and on service results to date.

Stack Design

In a paper entitled "Design of Chimneys to Control Downwash of Gases" **R. H. Sherlock** and **E. J. Lesher** of the University of Michigan analyzed typical patterns of gas behavior. Starting with the concept of a basic plume from a plant in level country and stable atmospheric conditions, the authors showed some of the principal patterns of dispersion and diffusion. Mention was made of the effects of unfavorable terrain, stack gas temperature and several factors in combination.

Studies to determine the laws of behavior of stack gases as they flow down wind have been in progress at the University of Michigan since 1934 under the sponsorship of the Commonwealth Edison Co. of Chicago. The wind tunnel in which the investigations were conducted is 8 ft wide by 5 ft high with a Venturi working section approximately 14 ft long. The velocity of the approaching undisturbed wind is kept at 20 ft per sec and gas is emitted from the stacks of the model at 70 F. The velocity of the stack gases can be varied.

An illustrative case was presented for a 300,000-kw two-stack power plant in which the discharge velocity at full load is 60 ft per sec at 335 F. Computations were made to show the number of hours that the bottom of the basic plume would be below 150 ft in each of the eight cardinal compass directions, assuming a stack height of 350 ft and full operating load for the entire year.

Coal-Fired Gasifier

P. R. Grossman and **R. W. Curtis** of The Babcock & Wilcox Co. described a pilot-plant pulverized-coal gasifier installed at the Morgantown Station of the Bureau of Mines and a semi-commercial gasifier of similar design installed by the du Pont Co. at its Belle Works in West Virginia. A brief summary of the operating data obtained from the two units was given in their paper entitled "Pulverized-Coal-Fired Gasifier for Production of Carbon Monoxide and Hydrogen."

The two units are quite similar, each being fired with two burners through which pulverized coal, oxygen and superheated steam are introduced into a refractory-lined furnace. The combustion chamber is divided into a primary and a secondary zone. In the primary zone molten slag is continuously tapped from the bottom of the chamber. The secondary zone is designed for lower gas temperatures and the accommodation of ash in a semi-plastic state. A small heat-recovery section has been installed at the top of the unit to simulate a waste-heat boiler. The dry-gas analysis from these units normally consists of about 40 per cent hydrogen, 40 per cent carbon monoxide, 15 per cent carbon dioxide, less than 1 per cent methane and approximately 4 per cent inert matter. The Bureau of Mines Unit has a nominal rating of 500 lb of coal per hour, producing 330,000 cu ft of carbon monoxide and hydrogen per day; it has been in service for about 1200 hr, mainly on short-duration tests. The du Pont gasifier has operated more than 5000 hr, its rating being 3000 lb of coal per hour and over 2,000,000 cu ft of synthesis gas per day.

Manpower and Other Factors Affecting Operating Costs

Diminishing returns from advances in steam conditions make it necessary to give closer attention to the effect of basic plant design upon the total station payroll, according to **V. F. Estcourt** of Pacific Gas & Electric Co. He cited the ever-increasing size of boilers and turbines, the unit arrangement and centralized control as factors having the greatest effect on manpower requirements. Drawing upon data from several steam plants of his company's system, he presented some charts to illustrate these points. One of these, here reproduced, shows the effect of unit size on manpower requirements for four 156,000-kw units at the Pittsburgh Steam Plant.

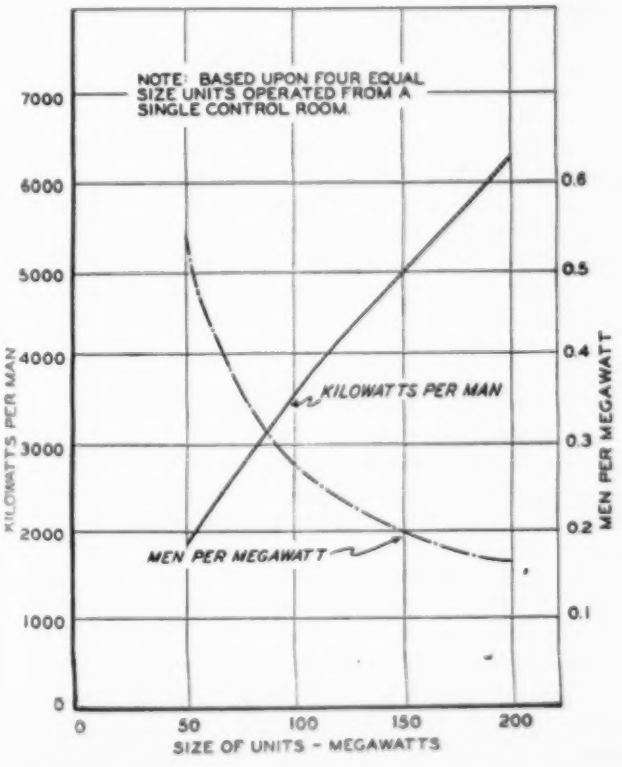
Despite the advantages of centralized control, Mr. Estcourt warned that concentrating the control of too many units sets up the danger of some catastrophic situation wiping out the controls of many large units on a system. Because of this possibility, controls of certain recent PG & E units have been so arranged that the essential individual unit controls are decentralized on panels located at each boiler and turbine. The central control room for four units can be handled from a combination bench and vertical panel, but in the event of the central control being put out of service, operation of the plant can be carried out from the local panels.

There are some features of plant layout that will result in reduced operating manpower only in conjunction with certain policies relative to the type of operators and the manner in which their duties are assigned, as, for instance, the kind of fuel and the location of major auxiliaries. In most instances the burning of solid fuel will require an additional shift operator to look after pulverizers, feeders and ash handling; but with fuel oil and gas it is often considered advantageous to locate the boiler feed pumps on the control room level.

In addition to the basic types of fuel the number of different fuels burned in the same station has a definite influence upon manpower requirements. It is during the change-over from one fuel to another that extra demands are often made on the shift operator. In general, there are a number of burners and auxiliaries involved when changing from oil to gas and it is often difficult to avoid having an additional man or men on each shift to take care of such fuel changes.

It would be difficult to coordinate all the functional components of present-day thermal cycles without a large degree of centralized control and instrumentation. The greatly increased size of boilers with their added complications for the control of higher steam temperatures and with reheat introduces problems of inaccessibility and distance which can only be solved satisfactorily by centralized controls. However, in the author's opinion, it is not always desirable to rely upon more and more complicated controls to overcome inaccessibility where they may make it difficult for the operator to handle the equipment. Instead he favors arrangements aimed at maximum accessibility and avoidance of the use of additional controls when the purpose can be accomplished by the exercise of greater ingenuity in the fundamental design. In other words, the objective should be to centralize only those controls which really assist the operator in doing a safe and intelligent job.

EFFECT OF SIZE OF UNITS UPON MANPOWER REQUIREMENTS



Continuing the panel discussion on manpower and other factors affecting central station operating costs, **J. C. Falkner** of the Consolidated Edison Co. of New York compared the manpower requirements for the two 180-mw units nearing completion at the new Astoria Station with two topping units of 110-mw equivalent capacity in the 1949 modernization program at Waterside Station. Astoria has a high degree of centralized control in one location, while Waterside has separate boiler, turbine and electrical boards. The result is that there is an average of 6400 kw per man at Astoria, as contrasted to 1800 kw per man at Waterside. It should be noted, however, that approximately the same number of men are required for either one- or two-unit operation at Astoria.

W. V. Drake and **D. H. Riley** of West Penn Power Co. commented that in the past station manpower requirements were too often considered as an afterthought to design. Among the factors which should be considered, studied and built into a station to keep down operating costs are its location, construction and layout, including the control room; type and make of equipment; fuel-handling and maintenance facilities; space for storerooms, storage, offices, and lockers; and special cleaning and janitor equipment. Once a plant is in operation, the following factors are worthy of consideration in order to make possible additional savings:

1. Employee morale, to which is related good supervision.
2. Adequate but not excess maintenance personnel.
3. Making permanent additions to force only after thorough study.
4. Minimum testing, engineering, clerical, purchasing and personnel work at the station.
5. Constant attention to better engineering, materials, methods, material handling and storage.
6. Proper and adequate accounting methods.

Since one of the principal reasons for use of centralized control is to reduce manpower and operating costs, **J. D. Williamson** of Dayton Power and Light Co. urged that full advantage be taken of potential savings from automatic equipment. Equally careful study should be made with regard to size of crews outside the control room. One possibility is to start with a minimum crew which may require occasional overtime work but will enable a satisfactory determination of the need for an increased force.

Transition Welds Between Ferritic and Austenitic Steels

G. E. Lien of American Gas and Electric Service Corp. and **F. Eberle** and **R. D. Wylie** of The Babcock & Wilcox Co. presented a paper entitled "Results of Service Test Program on Transition Welds Between Austenitic and Ferritic Steels at the Philip Sporn and Twin Branch Plants." At these stations which operate at 2000 psig, 1050 F, the superheater outlet tubes and the main steam header are of ferritic material, while the stop valves are of austenitic material. A conventional butt weld was selected for the transition joint, using the following procedure: 20 deg U bevel welding groove, tapered type

347 backing rings, 480–750 F preheat and interpass temperature during welding, type 347 filler metal, 1100–1200 F stress relief on the ferritic side, gamma ray and fluorescent penetrant postweld inspection.

In order to study the behavior of these welds under operating conditions, a test vessel was made of the same materials and to the same dimensions as the main steam header, its center weld being an exact duplication of the transition welds at the stop valves. The vessel is piped into the main steam header with a pressure drop of 200 in. of water across it. Provision is made in the valving so that the test vessel can be cooled independently of the main header. The procedure has been to close these valves once a week, so that the vessel cools to approximately 300 F in about 22 hr.

Experience with the test vessels totals 102 cycles at Philip Sporn Unit 1 and 158 cycles at Twin Branch Unit 5. It has demonstrated that ferritic-austenitic weld joints subjected to thermal cycles between 980–1010 F and 300 F may develop not only oxide notches or cracks at the surface but also cracks below the surface. Both types seem to occur only in the low-alloy steel in a region adjacent to the dissimilar weld fusion interface. Those at the surface appear to be of the stress-oxidation type, whereas those below the surface originate in the absence of oxygen.

The authors concluded that the propagation of the cracks under the operating conditions existing at the Philip Sporn and Twin Branch plants appears to be rather slow and encourages the belief that the dissimilar welds in the main steam lines (which are subjected to much less frequent thermal cycles than the test vessels) are in no danger and will give many years of safe operation. The test program is being continued, and two additional type welds are under study.

A second paper on the testing of welds joining austenitic and ferritic steels was presented by **H. Weisberg** and **H. M. Soldan** of Public Service Electric and Gas Co. under the title of "Cycle Heating Test of Main Steam Piping Materials and Welds at Sewaren Generating Station." This represented a continuation of tests described in a paper prepared by Mr. Weisberg for the 1948 ASME Annual Meeting. In the current test a section made up of austenitic and ferritic piping and welds was subject to thermal cycling from room temperature to 1100 F and from atmospheric pressure to 1500 psig. Heating and cooling rates were somewhat more severe than are experienced during regular starting and shutting down conditions in the actual piping systems.

The test section consists of nine pieces, three forged ferritic, two forged austenitic, three cast austenitic and one austenitic-ferritic transition piece. Welded joints represent actual shop and field welds made with the techniques used in the installed station piping. The test section was connected to the main steam piping of the No. 1 Unit at Sewaren, and the outlet was piped to the condenser. A gas-fired furnace was installed in the steam feed to supply additional heat to the steam before admission to the test section, while a desuperheater was provided for use in the cooling cycles.

The test comprised 100 cycles, of which five simulated rapid heating (corresponding to the maximum observed rate of $^1/_3$ deg per sec) after which the temperature was maintained constant at 1100 F for one hour, followed by rapid cooling similar to carryover conditions. The next 95 cycles were to simulate the maximum heating and cooling rates encountered during normal startup and shutdown periods. To approximate the aging process to a moderate degree, alternate cycles were given an additional overnight soak at 1100 F, 1500 psig. The total cycling time for 100 cycles was 2803 hr, of which 140 hr were heating, 105 hr holding at 1100 F, 2456 hr holding at 1000 F and 102 hr cooling.

In the test no cracking was observed which could be attributed to thermal cycling. Microfissures and star cracks visible at the start of the test did not propagate. There was a notch due to scaling on the ferritic side of the junctions, but no propagation appeared. No defects were found in the ferritic-austenitic transition piece other than the scaling just mentioned.

On the basis of two series of cyclic tests and operating experience over a five-year period the authors concluded that failures will not occur under conditions which may be encountered in normal operation during periods representing a major portion of the unit's life. More severe conditions are necessary to produce cracking or failure, and it is planned to continue cycling the section now under test with the application of external bending forces and possibly using higher temperatures for aging.

Properties of Weld Deposits

In a paper entitled "The Stress Rupture Properties of Some Chromium-Nickel Stainless-Steel Weld Deposits," **R. D. Wylie** and **W. E. Leyda** of the Babcock & Wilcox Co. and **C. L. Corey** of the University of Michigan presented data on the strength of all weld-metal coupons of eleven compositions of commercial stainless-steel weld deposits. Although the principal testing temperature was 1200 F, the range was from 1050 to 1500 F and testing periods ranged from 2000 to 16,000 hr. The tests showed that weld metals generally have lower rupture strength than wrought metals of corresponding chemical analysis, particularly at temperatures above 1200 F. Deposits which were columbium stabilized gave evidence of better stress-rupture properties than those without columbium. It was also found that austenitic weld deposits exhibit low rupture ductility at elevated temperatures as compared with corresponding wrought materials. The authors reported that there may be some possibility of improving rupture ductility by means of chemical and structural modifications of austenitic materials.

Steam at 2000 Psig, 1250 F

It will be recalled that a paper[1] at the 1951 Annual Meeting dealt with the performance of certain alloys at 1250 F as determined by an experimental superheater in one of the 2000-psi 950-F boilers at the Twin Branch Generating Station. This consisted of a 2-in. OD element in the form of four hairpin loops in series and so placed in the gas path as to raise the temperature of the 950-F steam to 1250 F. It was first installed in 1950.

A current paper by **F. Eberle, F. G. Ely** and **J. A.**

[1] See ASME *Transactions*, Vol. 74, July 1952; also COMBUSTION, December 1951.

Dillon, of Babcock & Wilcox Co. was in the form of a progress report on this investigation and included information derived from metallurgical examination of a number of specimens removed from the element after nearly 7000 hr of operation. The original materials variously arranged in the loops were as follows:

	Cr	Ni	Mo	Other Elements
Croloy 2¼	2.25	..	1	..
Type 304	18	8	..	..
Type 347	18	8	..	Cb
Type 321	18	8	..	Ti
Type 316	16	13	3	..
Type 318	16	13	3	Cb
Timken 16-25-6	16	25	6	..
Armco 17-14 Cu-Mo	17	14	2.5	3 Cu-Cb-Ti

Virtually all the original materials are still in service, and advantage was taken of the opportunity to install specimens of a new experimental alloy, also to utilize the high-temperature steam for corrosion tests of conventional superheater steels. The new materials were unstabilized and included 18–8 (A151-304) and a superstrength alloy, HDN.

The AISI-Type 316 alloy displayed the highest corrosion rate and showed some evidence of incipient intergranular surface attack. Indication of intergranular surface oxidation also was noted on the outside of the 16–25–6 alloy which showed the second highest scaling rate. Also, the nonstabilized alloys AISI 304 and 316 experienced carbide precipitation at the grain boundaries although there was no indication that they suffered intercrystalline corrosion attack by steam.

In conclusion, the authors stated that examination of the tube sections removed after 6950 hr of operation showed no serious impairment of essential properties in any of the alloys employed. However, among the weld metals, 18–12 Mo and 17–14 CuMo suffered considerable impact embrittlement, but an improved 17–14 CuMo electrode has since become commercially available. They further expressed the opinion that commercial use of superheaters operating with steam above 1200 F is not too distant.

Piping Studies

In 1951 a task force was formed by the American Standards Association to study and report on the adequacy of current provisions on expansion and flexibility in the Code for Pressure Piping. **A. R. C. Markl** of Tube Turns, Inc. sought to present the consensus of this task force in a paper entitled "Piping Flexibility Analysis." The paper aims to outline the various phases of the problem, with particular emphasis on the phenomena of plastic flow and fatigue encountered in piping system operation. It introduces the concept of a limiting-stress range rather than an allowable stress as the criterion of the adequacy of a layout.

Calculation of the reactions and stresses in a piping system is complicated by peculiarities of stress and strain distribution in certain piping components under bending. One of the effects is to endow such fittings with what is usually greater flexibility than would be predicted from ordinary beam theory. A flexibility factor is commonly used in calculations to take care of this. It can be defined as the ratio of the rotation per unit length of the part in question produced by a moment, to the rotation per unit of length of a straight pipe of the same size and schedule produced by the same moment. It is applied either as a multiplier of the length of the part, or as a divisor of its nominal moment of inertia or of the elasticity modulus.

The author illustrated the application of this concept to a number of types of fittings. He also discussed the use of stress-intensification factors, self-spring and cold-spring effects and allowable stress range and reactions in piping.

J. E. Brock of the Midwest Piping Co., Inc. presented a paper entitled "Flexibility of Piping Systems Supported by Equally Spaced Rigid Hangars" in which he developed exact methods for the analysis of single-plane piping configurations in which there occur long horizontal runs. An example was worked out to show the use of the method on a 500-ft length of 8-in. pipe carrying 150-psig, 366-F steam and supported at 20-ft intervals with a U-bend located at an intermediate point. A second example showed the application for a zee bend in a section of 6-in. standard pipe carrying steam at 250 psig, 406 F.

A paper entitled "Elastic Constants and Coefficients of Thermal Expansion of Piping Materials Proposed for 1954 Code for Pressure Piping" was presented by **Rudolf Michel,** Bureau of Ships, Navy Department. Dynamic methods of determining elastic constants agree closely with static methods for temperatures where creep is negligible. Above this temperature wide differences occur between the two methods. Elastic constants determined by static methods are recommended for use above the temperatures mentioned when making thermal-stress computations of hot piping systems. Such data are not only meager at present, but the method of making the static test for moduli at elevated temperatures has not been standardized. With different techniques rather large variations in results are obtained. A recommendation is made to standardize the number of test specimens to be used for each temperature, method of bringing specimens up to temperature, range of stress to be covered during test, and length of time under load.

Heat Transfer

In keeping with U. S. industry's concern for more fundamental research a number of rather theoretical papers were sponsored by the Heat Transfer Division. Most of these papers dealt with fundamental properties of gases and liquids and their behavior when exposed to heat.

"Convective Heat Transfer for Mixed Free and Forced Flow Through Tubes," by **E. R. G. Eckert,** professor, mechanical engineering, University of Minnesota, as well as consultant to the Lewis Flight Propulsion Lab., and **Anthony Diaguila,** aeronautical research scientist, Lewis Flight Propulsion Lab., was concerned entirely with the problem of heat transfer under the simultaneous influence of forced and free convection for flow through circular tubes. Heat exchange in oil coolers is affected by free-convection currents superposed to the forced flow. This same combination of convection currents applied,

however, in a different way appears in the cooling of rotating parts such as the rotor blades in gas turbines and ram jets. The authors discussed in detail their investigations of local heat transfer coefficients in mixed flow through tubes. They combined their results with analytical and experimental ones of previous investigations to form a survey of the research to date and a collection of the available information on convective heat transfer in the mixed-flow regime.

Newman A. Hall, professor of mechanical engineering, and **Warren E. Ibele,** assistant professor, University of Minnesota, presented a report on "The Tabulation of Imperfect-Gas Properties for Air, Nitrogen and Oxygen." Recent theoretical investigations on intermolecular forces, the authors explained, established a basis for a fundamentally valid extension of gas-property data, particularly thermodynamic. These intermolecular forces modify the perfectly elastic impacts of a simple kinetic theory gas model and indicate there are decided deviations from perfect-gas behavior. The greater the gas pressure, the more the gas molecules are pushed together at higher densities and the molecular interaction effect becomes more pronounced. This paper established the fact that deviation from perfect-gas behavior may be expressed by the compressibility factor. Tables of virial coefficients and temperature derivatives were given, as well as compressibility factors for these gases.

Still another primarily fundamental paper, "Kinetic Theory of Evaporation Rates of Liquids," by **E. F. Lype,** senior research engineer, Armour Research Foundation, was developed to explain, from theoretical considerations, the surprisingly low rates of evaporation found in numerous reliable experiments of different observers. At the point of thermodynamic equilibrium the evaporation rate is equal to the condensation rate, so that any theory that explains the one should explain the other. For this reason Mr. Lype approached his research with the kinetic theory method. The relations controlling the vapor-liquid equilibrium have formerly been calculated from the kinetic theory of gases for the case where all molecules striking the interface from the vapor phase condense and become part of the liquid phase. This oversimplified relationship holds for some liquids but as the author pointed out it failed in the case of water, a pseudo-crystalline liquid. The discrepancy for water between reliable experiments and the value calculated from conventional theory brought out this failure very strongly. Mr. Lype cited the experimental data from a number of reliable studies for condensation, and evaporation rate was of the order of 1 per cent of the indicated calculated value. As a result he directed his research along the lines of the Polanyi-Wigner theory of escape of molecules from the surface of a solid, and Volmer's application of this theory. Graphs were presented that show good agreement between theory and experiment by this method.

Use of Residual Fuel Oil

Under the sponsorship of the Gas Turbine Power and Fuels Division a panel discussion was presented on residual fuel for gas turbines. Taking part were two representatives of gas turbine manufacturers, **B. O. Buckland** of General Electric Co. and **A. E. Hershey** of Westinghouse Electric Corp.; two from users of gas turbines, **Frank Fahland** of the Union Pacific Railroad and **H. F. King** of the U. S. Navy Dept; a metallurgist, **C. T. Evans, Jr.,** of Univeral-Cyclops Steel Corp.; and four engineers from oil companies, **O. F. Campbell** of Sinclair Oil Co., **L. J. Grunder** of Richfield Oil Co., **C. W. Hoffman** of Socony-Vacuum Oil Co., and **A. S. Orr** of Gulf Oil Corp.

In general the representatives of the oil industry were pessimistic about both the quantity and quality of future residual fuel supplies. It was pointed out that some of the newer refining processes, such as the combination of coking with catalytic cracking, can be carried out without producing any residual fuel at all. Although this is not likely to happen, the trend of less residual oil per barrel of crude oil is expected to continue. In the early refineries, residual fuel reached as high as 40 per cent of total production; today it is about 18 per cent, and the prediction was made that it will be down to 10 per cent by 1970. There is the possibility of blending certain fractions of low ash and vanadium content derived from catalytic cracking, but the cost of the blended fuel will be higher than residual fuel. Mention was made of the use of additives, but there was sharp disagreement as to whether they should be added at the refinery or by the user. At least one oil company is prepared to supply residual fuel to meet stringent specifications for gas turbine use.

Representatives of gas turbine manufacturers agreed that one of the problems was to be able to specify an oil which could be reordered and reproduced over a long period of time. In the first gas-turbine installations most of the difficulties were encountered from corrosion. Some solutions have been found to this problem, but now the matter of ash in the residual fuel oil is assuming greater importance. A specification recently proposed would limit total ash content to 2000 ppm, with sodium and calcium content not to exceed 10 ppm each and a preferred value of 5 ppm. It is also proposed that the ratio of the weight of sodium in the ash to that of vanadium should not be greater than 0.3, and that the ratio of the weight of magnesium in the ash to that of vanadium should not be less than 3.0.

It was reported that eight gas-turbine locomotives on the Union Pacific Railroad had operated over a million miles burning residual fuel oil up to November 1953. As defined in railroad practice, these locomotives had an availability of 80.5 per cent. Filtration of fuel aboard the locomotives leaves much to be desired, so wayside filtration plants are being installed. Other fuels, including propane and distillate, are being tried to determine the effect of the various fuels on locomotive operation. In marine applications, salt water contamination must be guarded against. There was some feeling that distillate fuels might be preferred until marine installations exceed a moderate amount.

Corrosion Control

Combatting corrosion in power plants continues to hold its place as one of the prime considerations for good operation. A two-paper session on Low-Temperature Corrosion served one phase of this interest. One of these

papers "The Use of Additives for the Prevention of Low-Temperature Corrosion in Oil-Fired Steam Generating Units" by **E. C. Huge** and **E. C. Piotter** of Babcock & Wilcox Co. was a follow-up of a 1952 Annual Meeting paper discussing test results with oil additives on ash deposits in the high-temperature zones of certain of the Inglis Station, Florida Power Corp., steam generating units.

Sulfur trioxide is held by the authors as the major cause for low-temperature corrosion, particularly at the cold end of the air heater. Further vanadium and other mineral impurities in fuel oil aggravate the problem greatly. To date no material has been found that can resist corrosion by itself. As a result investigations have been underway to identify additives that will inhibit the corrosion action of oil's impurities. The authors believe dolomite is especially gifted for additive duty.

The paper reported dolomite (1) reduced the amount of free sulfur trioxide in the flue gas thereby lowering the dewpoint, (2) scrubbed over the tube surface to neutralize any acid paste formation and kept the surface dry.

A second paper on this same session, "The Influence of Fine Particles on the Corrosion of Economizer and Air Preheater Surfaces by Flue Gases" by **Peter Hodson** of Air Preheater Corp. began with the premise that sulfur compounds in the fuel—coal, in this case—are the origin of flue gas troubles. In the presence of iron the sulfur compounds' attack produces ferric and ferrous sulfate with the former a catalyst that aids the formation of sulfur trioxide from sulfur dioxide. In brief a vicious circle is soon established with corrosion products aiding and abetting the development of still more. In addition to this more or less well known condition the author introduced the factor of the fine particles on the corrosion problem.

These fine particles, or cenospheres, speed up the reaction rate of corrosion. And they do so because they present such an enormous surface for chemical activity, such as adsorption, between the flue gas components and the various oxides and sulfur compounds making up the individual fly ash particles. Over and above this purely chemical phase is a physical chemical one. The small particles serve as excellent condensation nuclei so that condensation of the vapors in the flue gas can occur at temperatures higher than the saturation point. This, of course, still further adds to the corrosion control problem. The author's company is now engaged in determining methods of collecting these very fine particles at high temperatures and what effect their removal has on plugging of economizer or air heater surfaces.

Water Treatment

The Boiler Feedwater Studies Committee set aside one session for the discussion of corrosion and some of its preventive measures. The session featured papers by **C. E. Kauffman, W. H. Trautman** and **W. R. Schnarrenberger,** Hall Laboratories, **H. A. Grabowski,** Combustion Engineering, Inc., and **C. Jacklin,** National Aluminate Corp.

For the lead paper of the session, Mr. Kaufman picked the subject of bonded oxygen and its rôle in attacking boiler metal. The term, bonded oxygen, is meant to represent the oxygen of constitution in the water. Compared to the traces of dissolved oxygen that can enter a well-operated boiler the reservoir of bonded oxygen is tremendous. Water contains 88.9 per cent oxygen but, obviously, all of this is not to be considered as potentially capable of reacting with the boiler steel. Yet, Mr. Kaufman pointed out, some of it very likely is.

Several case histories were presented to show what has happened when bonded oxygen deposits had reacted with steel. The Winkler test for dissolved oxygen in the feedwater of the crippled boilers consistently gave zero results. The conclusion in the author's mind, was unquestionably bonded oxygen. Several suggestions were advanced on ways of preventing bonded oxygen attacks. Of these the broad and basic ones are local rate of heat input, local completeness of rinsing, and character of the boiler water. As further aids the author suggested (1) deaeration followed by chemical scavenging, (2) alkalinity levels kept to the point that gives best overall conditions for the particular boiler service, (3) refractory baffling and insulation maintained in good repair, (4) surface rinsing and, where this is considered marginal, employment of mechanical aid such as tube spirals, (5) chemical cleaning of any boiler suspected of containing accumulations of corrosion products and (6) treatment of the water system to prevent feedwater and condensate pickup of outside materials.

Discussion

I. B. Dick, Consolidated Edison Co. of New York, in discussing the paper brought up the point that more basic research was needed on the fundamental action of water in iron. In addition the effectiveness of sulfite, particularly, as a scavenger of dissolved oxygen, was held to be extremely questionable in Mr. Dick's judgment.

A. R. Mumford, Combustion Engineering, Inc., followed up the theme of a need for more research. He especially referred to two common but vague water treatment control suggestions as indicative of the need for more definite data. These suggestions are frequently made in the form of avoiding too high a heat transfer or too low a circulation velocity.

The paper "Experimental Boiler Studies of the Breakdown of Amines" by Mr. Jacklin was definitely in the research field. It recounted the results obtained when several amine types were tested for breakdown to ammonia in an experimental boiler. Test pressures ranged from 250 psi to 2500 psi and temperatures went from 400 to 1200 F.

Morpholine, already successfully used at 1600 psi and 1000 F, indicated a relatively good stability at 2500 psi and 1200 F. A table was presented listing the different amines under study (some fifteen) and their breakdown experiences under the different test conditions. Morpholine, in the author's opinion, most nearly fulfills the requirements for an ideal volatile alkaline material for pH control in steam generating systems.

Mr. Grabowski's paper "Corrosion of Steel In Boilers—Attack by Dissolved Oxygen" called attention to (1) the lack of consistent conclusions on the exact role of dissolved oxygen in the corrosion of internal surfaces,

(2) the maximum concentration that can be tolerated, (3) the exact cause of the initial pit formation at the tube surface. After reviewing the various theories proposed to explain the severe, though local, corrosion of furnace wall tubes in high pressure boilers the author presented results of a number of field tests in utility type boilers.

The field experience indicated that tube failures occur where poor deaeration is known to take place with most severe attacks where the oxygen in feedwater periodically goes to more than 0.05 ppm. Mr. Grabowski recommended the use of an oxygen scavenger and special attention to oxygen invasion during low load, night and week-end operation.

A paper entitled "The Solubility of Nitrogen and Hydrogen in Water," by **S. N. Suciu** of the General Electric Co., **L. M. Zoss** of Taylor Instrument Co. and **W. L. Sibbitt** of Purdue University presented results of a study conducted at Purdue University. The solubility of nitrogen in water was measured at 500, 1000, 1500, 2000 and 3000 psia and at temperatures from 32 to 500 F. The solubility of hydrogen was measured at 1000, 1500, 2000 and 3000 psia and at temperatures from 32 to 635 F.

Both hydrogen and nitrogen are very soluble in water at 32 F. The solubility decreases with increasing temperature until a minimum value is reached, usually at a temperature below 200 F. Then the solubility increases without limit as the critical temperature of water is reached. It was also found that Henry's Law does not hold at pressures much above 1000 psia.

Free-Piston Engine

Continued interest in the free-piston engine was evidenced in a paper by **Prof. A. L. London** of Stanford University entitled "The Free-Piston and Turbine-Compound Engine—A Cycle Analysis." It is the belief of the author that the major virtues of this type prime mover are low cost, mechanical simplicity and flexibility in application as a result of turbine drive, together with high thermal efficiency. The free-piston engine is competitive with the diesel engine on a thermal efficiency basis, though Prof. London felt it unwise to make extravagant claims for fuel economy. The thermodynamic cycle for the free-piston engine has some of the inherent flexibility of the gas-turbine cycle in that variations such as supercharging, with or without intercooling, and reheating are possible. When reheat is employed the free-piston engine has a lower specific weight than the diesel.

In making the cycle analysis perfect gas behavior is assumed, together with suitable averaged values of specific heat. The influence of compressor, turbine and mechanical inefficiencies and the effect of valve pressure drops and coolant-jacket heat transfer are included. The calculated parameters of specific flow rate, specific fuel consumption and turbine inlet temperature are found to be in reasonable agreement with test data now available. Results of the analysis clearly indicate the importance of component losses on turbine inlet temperature and plant specific fuel consumption and point out the unique characteristics of the cycle. A study of methods of load governing leads to the conclusion that a variable-area nozzle turbine may be necessary if the flat part-load economy of the diesel engine is to be realized by the free-piston engine.

Gas-Turbine Cooling

Blade cooling has appeared to be an attractive means of operating gas turbines at higher inlet temperatures than would otherwise be possible. A paper entitled "A Novel Cooling Method for Gas Turbines" by **Edward Burke** and **G. A. Kemeny** of the Westinghouse Research Laboratories discussed the cooling of turbine blades by direct water spray. Water is supplied from orifices in tubes located near the trailing edge of the turbine nozzle guide valves. The liquid impinges on the rotor blades forming a layer which serves both to insulate the blade from the hot gas stream and to extract heat from the blade. Results of experiments on a supercharger, with gas temperatures between 1150 and 2350 F, and theoretical studies of the effect of spray cooling on cycle efficiency indicate that both the output and efficiency of the gas turbine plant should be increased. For the spray rates required in the tests, approximately one-third of the increase in efficiency made possible by higher temperatures is lost due to cooling. If cooling of a practical turbine could be accomplished with only one-third as much water, these losses would be proportionally reduced. Increases in output made possible by higher gas temperatures are virtually unaffected by spray cooling.

Atmospheric Pollution

As a follow-up of 1952's highly successful symposium on air pollution, responsible spokesmen from New York, Los Angeles, Great Britain and Canada were brought together at this year's symposium to report on their particular area's air pollution control situation.

Out in Los Angeles, as **P. L. Magill** and **F. E. Littman** of Stanford Research Institute reported, there has probably been more scientific effort devoted to air pollution control than at any other location at any time. The overall problem has involved technical, legal and political aspects.

At the present moment severe smog still exists in the Los Angeles area. Stanford Research has been at the job for the past five years of digging out the reasons for this stubborn smog. These studies have run the gauntlet of climate investigations as far back as records permitted, population trends for the last thirty years, geographic and meteorological factors, and lastly, collections and analyses of particulate matter, solid or liquid, in the atmosphere. The most recent efforts have been focused on the effects that these pollutants have by themselves, on one another, and in the presence of ozone which, oddly enough, reaches 30 to 40 pphm during periods of severe atmospheric pollution.

This last observation of high ozone concentrations, some five to six times as high as had been reported up to that time anywhere else in the world, set off a string of special investigations. These investigations revealed

concentrations of ozone as high as 45 pphm near Fairbanks, Alaska, 28 pphm at Detroit, but oddly enough a narrow range from 0 to 6 pphm in New Jersey with a year of continuous measurement. Professor A. J. Haagen-Smit of California Institute of Technology reported ozone can form as a result of sunlight reacting upon a mixture of hydrocarbons and nitrogen dioxide in the atmosphere. Crop damage begins to occur with ozone concentrations of about 15 pphm and eye irritation at 20 pphm.

One of the principal uncontrolled sources of air pollution in Los Angeles is automobile exhaust fumes. The two million automobiles in Los Angeles burn approximately four million gallons of gasoline daily and eject into the atmosphere about 4 billion cubic feet of exhaust gases.

These exhaust gases are a prolific source of liquid droplets and crystalline materials, as well as furnishing a significant portion of the total aldehydes, oxides of nitrogen and hydrocarbons released to the Los Angeles atmosphere.

The automobile and the backyard incinerator remain the two major pollutant sources as yet uncontrolled that offer promise of immediate gains. In the past five years there has been an estimated 600 tons per day of known pollutants eliminated. There is less sulfur in the air than in the early 1930's. Yet the fall of 1953 saw some of the most severe smogs in Los Angeles history. The one hope the authors hold out is that more research may identify the exact causes of ozone and the control of ozone's influence on air pollution problems.

E. A. Allcut, head of the Department of Mechanical Engineering at the University of Toronto and chairman of both the Smoke Abatement Advisory Board of Toronto and the Committee on Atmospheric Pollution in Canada, traced the growth of air pollution controls and laws in Canada. By and large these laws, all local in character, have been framed around a guiding rule laid down by S. B. Flagg of the U. S. Bureau of Mines back in 1913 as follows: "The requirements should represent the best practice, the standard set should not be an impossible nor an impracticable one, neither should it represent ordinary or poor practice." Education and persuasion are preferred to coercion, and only in recalcitrant cases is the offender prosecuted.

Professor Allcut also expressed the conviction of Canada's national committee that air pollution problems are basically regional, and not municipal or federal, so that laws for their control should be under the jurisdiction of provinces. Further, this committee believes the crux of the problem is the amount of pollutant emitted and not its density in stacks of different sizes.

E. T. Wilkens, Atmospheric Pollution Research, Fuel Research Center, London, England, confined his paper almost entirely to the December 1952 London smog which he termed the world's most disastrous one and held it chiefly responsible for the deaths of about 4000 people. Measured daily concentrations of smoke and sulfur dioxide were up to 1.3 ppm, about ten times normal for that time of year. Unlike Donora in 1948, and Liege, Belgium in 1930 there were already set up some measuring stations which regularly took smoke and sulfur dioxide samples. The measuring methods were described and certain estimates were made on possible carbon monoxide concentrations. Highlight of the paper was a very controversial chart plotting daily deaths, smoke and sulfur dioxide concentrations against the December smog dates.

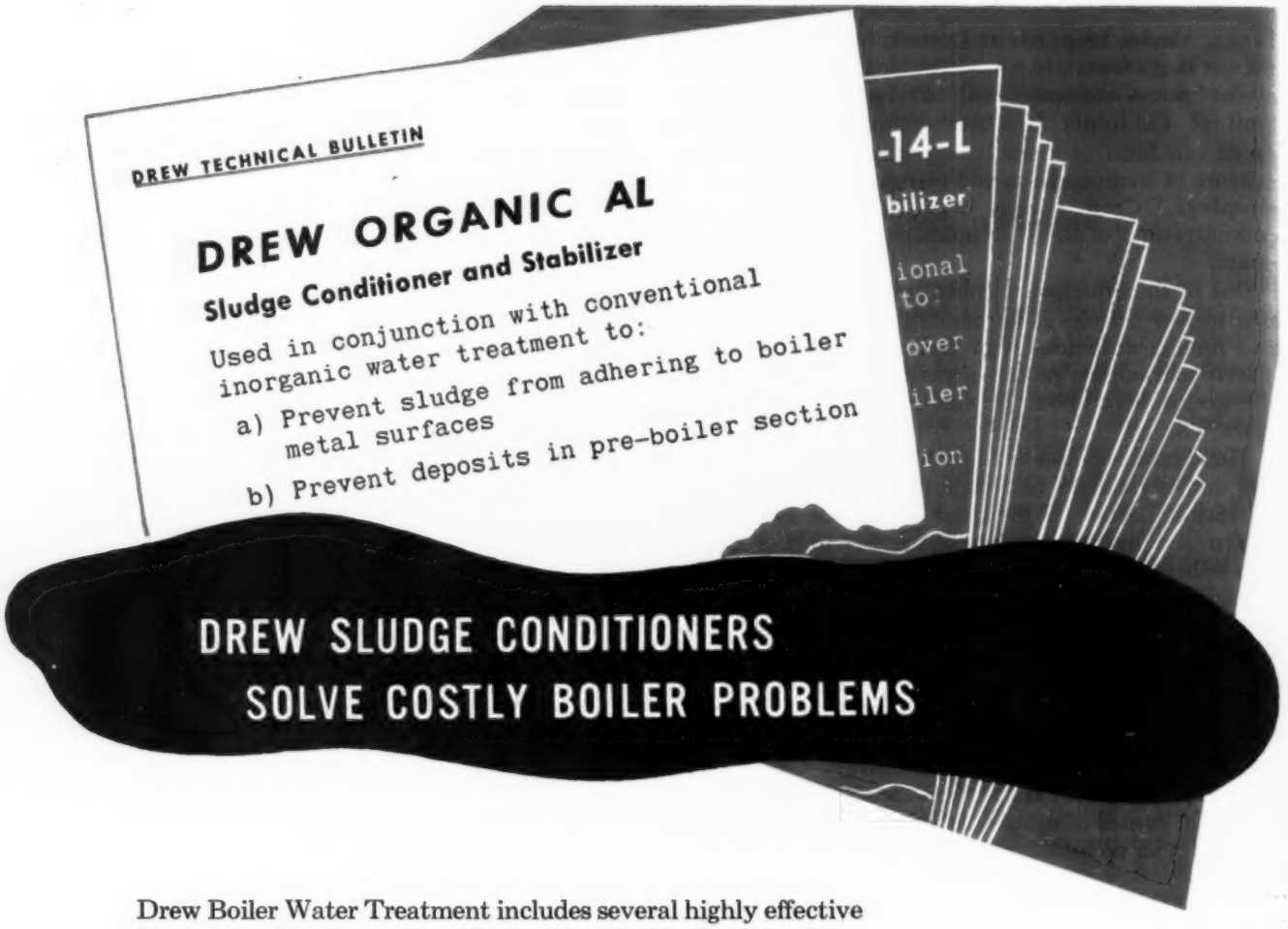
Dr. Leonard Greenburg, New York, reviewed the important aspects of air pollution control in modern American cities and the lack of comprehensive background studies. He then discussed the major sources of New York City's air pollution and gave a number of interesting statistics on the extent of some of these pollutant sources. In summation Dr. Greenburg described the workings of New York's Air Pollution Control Department and the shortcomings of certain of its Rules and Regulations. He particularly found the Ringelmann Chart unsatisfactory for big city use and recommended instead a chart made by a photo-engraving process wherein the dots fuse visually at a minimum distance of 20-in. from the observer's eye.

While considerable progress has been achieved in the design and development of more efficient electrical precipitators, the fundamental problem of removing the collected dust from precipitator electrodes has become a serious limiting factor. The real difficulty arises in successfully transferring the material to the hoppers without significant loss due to re-entrainment, major disturbances of dust already in the hoppers, or interference with the electrical operation of the precipitator. Evidence of these losses appears over many power plants in the form of substantial stack clouding and puffs as the traditional intermittent rappings for dust removal are applied to the electrodes.

A paper presented by **H. J. Hall** and **T. A. Pierson** of Research Corp., "A Magnetic-Impulse Rapper System for Electrical Precipitators," discussed a new system for electrode cleaning that provides continuous rapping essential for elimination of stack puffs and, in effect, converts precipitation from a variable batch process to a continuous, uniform one. The authors claimed that the overall collection efficiency was also improved because uniform conditions are constantly maintained in the precipitation zones. Experience on over 700 operating units bears out the authors' views and attests to the value of sectionalized, continuous rapping of a closely controlled intensity.

Compressor Performance

In a paper entitled "The Analysis and Evaluation of Compressor Performance," **M. C. Stuart** and **T. E. Jackson** of Lehigh University presented data from a series of tests on a cooled and an uncooled multi-stage centrifugal compressor. By using collected data a comprehensive analysis of the energy transformation in both cooled and uncooled compressors has been made in an illustrative form. The first and second law energy analyses have been made for some idealized reversible processes between the same range such as adiabatic reversible compression, polytropic reversible compression, adiabatic reversible air engine working over a temperature range.



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Combustion of Low-Grade Coals

By L. P. CRECELIUS*

Following a discussion of factors responsible for clinker formation, excessive tube slagging and corrosion of heat-recovery surfaces when burning low-grade coals, the results of tests are given in which untreated coal is compared with the same coal chemically treated. The latter showed up better and indicated the advisability of a chemical approach to the problem of burning low-grade coals.

MODERN boiler furnaces, as now constructed, are surrounded by a labyrinth of heat-absorbing surfaces disposed so as to afford the utmost efficiency of heat transfer from the burning coal, by means of radiation and convection. It is every-day operating practice to run such furnaces with the air supply closely controlled with a flue gas analysis of some 14 to 16 per cent carbon dioxide, corresponding to 20 to 30 per cent excess air. This gives rise to maximum furnace temperatures of 2800 to 3000 F. The heat recovery surfaces have been extended so that the wasting of the gases of combustion takes place below 350 F. It is under such circumstances that serious difficulty is met with in the use of low-grade coal, high in sulfur-iron content.

Among the difficulties encountered in burning such coal under these conditions are:

Objectionable grate clinker formations,

Excessive tube slagging,

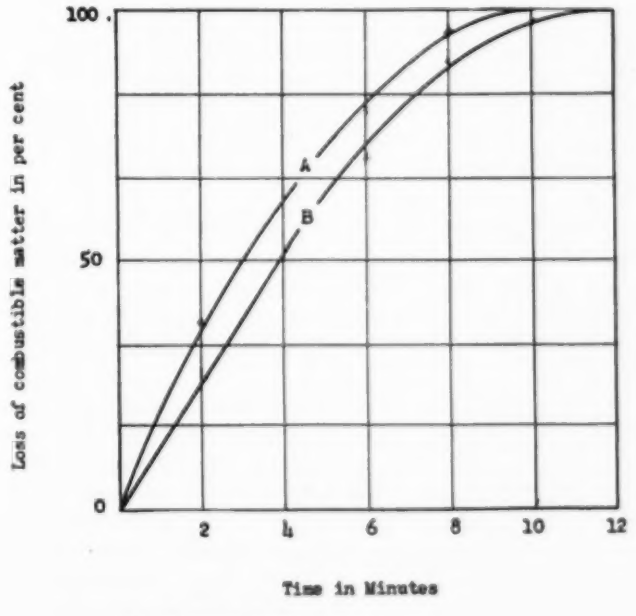
Corrosion of the low-temperature heat-recovery surfaces of the boiler unit.

Silica, alumina, iron and lime are the principal constituents of coal ash and are present in all coal in varying amounts. Sulfur occurs in coal and also varies greatly as to quantity and form; as iron pyrite or marcasite; as sulfide of iron, sulfates of alumina and lime; as organic sulfur combined with carbon, hydrogen and oxygen and in some cases in a free state, not combined with other elements.

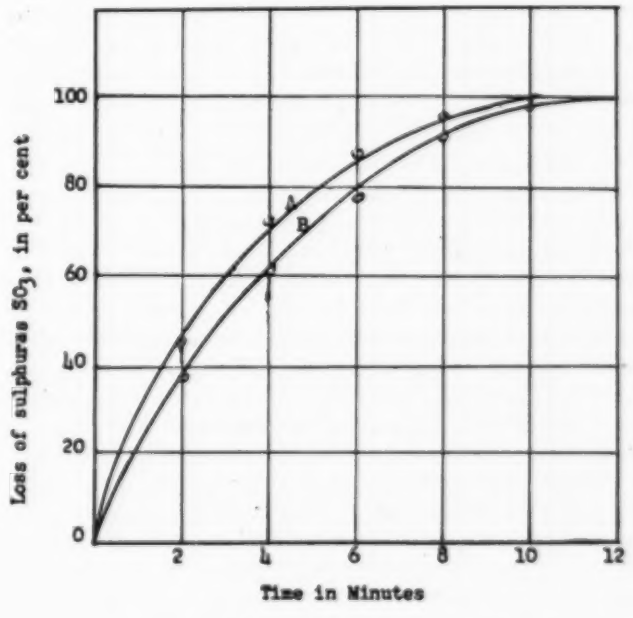
SULFUR—This is decidedly the principal cause of the difficulties enumerated above. Dr. Henry Fraser Johnstone of the University of Illinois, many years ago, conducted extensive and highly important research on this subject and, in an admirable article entitled, "Reactions of Sulphur Compounds in Boiler Furnaces" published in *Industrial and Engineering Chemistry*, June 1931, set forth this phenomenon in detail. He found that: "when coal is fired on a stoker about 30 per cent of the sulfur remains in the ash, a part of which exists as iron sulfide"; that "only about 2 per cent of the sulfur dioxide in the flue gases is oxidized to trioxide regardless of the temperature or oxygen content of these gases"; that "the hygroscopic nature of deposits containing ferric sulfate causes moisture to condense at temperatures considerably above the dewpoint of the gases etc."; and that "solutions containing ferric sulfate act as strong catalysts for the oxidation of sulfur dioxide to sulfuric acid."

GRATE CLINKERS—Iron sulfide is the cause of troublesome hard clinkers. In the fire at temperatures in excess

*Crecelius & Phillips, Engineers, Cleveland, Ohio.



(A) treated coal.
(B) untreated coal.



(A) treated coal.
(B) untreated coal.

Results with coke burned in an electric furnace at 2020 F (+ or − 10 deg); left-hand chart shows loss of combustible and right-hand chart loss of SO_3.

of 2000 F the ash-making constituents of the coal commence to flux and fuse together causing clinker formation. Since silica will not combine with iron when it is in the form of iron sulfide having a melting point of about 2140 F, it melts at fuel bed temperatures slightly above this and runs through the surrounding ash to the grate surface. The clinkering thus formed shuts off the air beneath the grate. The clinker and the grate surface become overheated. The sulfur of the clinker combines with the metal of the grate and becomes firmly cemented to it. Such a clinker is exceedingly difficult to remove without damaging the grates. This condition is much aggravated by the use of highly preheated air.

TUBE SLAG—Slagging of the tubes is caused by the partially oxidized coal particles escaping from the furnace and collecting on such of the tube surfaces exposed to the heat of the furnace. When bituminous coal is introduced into the fire, the process of combustion takes place in about the following manner: The coal absorbs heat which raises its temperature and the moisture is driven off; the carbon of the coal ignites and burns at around 800 F; the volatile matter (hydrocarbons) is distilled off and vaporized; next, the hydrocarbons become dissociated into their elements (H and C) by the temperature of the furnace before they can burn. These several steps take time, for there is a definite resistance to all chemical reactions.

Because of economic considerations involving the construction and cost of a boiler furnace large enough to burn the low-grade coals to better end-points, the furnace volume must of necessity be compromised, contemplating the escape of considerable unconsumed combustible matter, the amount depending upon what the traffic will bear. Therefore, as all the ash of the coal is contained in the fixed carbon, some of it in small partially burned particles is carried over to the tube surfaces by the velocity of the gases. Since these particles are at high temperature, more or less fused and plastic, they adhere to nearby tube surfaces and to one another and continue to smolder, there being little oxygen left in the flue gases, and because of the reducing action of the carbon present in these particles. In time they accumulate to considerable thickness. It is this conglomeration of partially oxidized carbon and ash, baked fast to the tubes and formed into a hard clinker, that is called tube slag.

CORROSION—It is in the lower temperature range (below 900 F) further along the gas path that the deposits on the tubes containing sulfates become stable. It is the presence of these sulfates collected on the tube surface that causes the formation of sulfuric acid from the sulfur dioxide of the flue gas. A relatively high sulfur content of the coal is usually an indication of much iron in its ash, expressed as Fe_2O_3. Thus such coals yielding more sulfur dioxide in the flue gases and more sulfates in the tube deposits, cause the formation of more sulfuric acid with an accompanying increase in the dewpoint of the vapor of the flue gas. This means that more of the low-temperature heat recovery surfaces are affected by corrosion. The low-grade coals are at a serious disadvantage in this respect.

The resistance to chemical reactions is much mitigated by high temperature and advantage of this is taken by operating the boiler furnace with a minimum of air supply. Below some excess air necessarily required, amounting to some 20 per cent, we cannot go, for carbon monoxide wasted by the flue gases increases steadily to severe proportions as we attempt to further approach the theoretical limit required to burn the coal. Therefore, we have a maximum temperature limit in the furnace of some 3000 F, more or less, and the maximum rapidity of combustion is thus limited correspondingly to such a temperature.

There are a number of chemical substances that have the property of greatly accelerating the speed of oxidation at a given temperature. Among these are the halogens which have such an effect to a marked degree at elevated temperatures. When, therefore, a relatively small amount of chlorine is added to the coal and then introduced into the fire a noticeable acceleration of burning takes place. The appended charts show the change that takes place in the burning of both the carbon and sulfur in the temperature range, where ferrous sulfide becomes unstable. At higher temperature this becomes much more pronounced. With better end-point oxidation of the carbon and sulfur, the clinker formation on the stoker grates and the exposed tube surfaces is altered as more of the iron it contains is taken into solution with the silica of the coal ash, producing a calcic ferro silicated slag. Such clinkers are more friable, less adhesive and more readily removable. A reduction in the amount of sulfates in the tube deposits is very important as explained in the opening paragraph on corrosion.

The results shown on the charts were obtained with a number of coal samples from which the volatile matter had been driven off in the usual manner. One-half of the samples were treated by adding a small quantity of calcium chloride, into which was incorporated the necessary oxidizing agents to decompose it completely at about 2000 F. The other half of the coal samples were not so treated. The remaining fixed carbon and ash were then subjected to the temperature indicated in an electric furnace. The samples, both treated and untreated, were checked at frequent intervals until the fixed carbon and sulfur were completely burned.

To study what effect, if any, this would have on burning the coal so prepared in a larger furnace, a practical test was made in a large modern power plant to which 1600 tons of coal were shipped, one-half of which was treated at the mine, and the remaining half not so treated. The sulfur in this coal was 4.01 per cent, its ash fusing temperature 2051 F, and its ash contained 31 per cent Fe_2O_3.

The test comprised 60 hr of operation in each case in the same boiler furnace and the results were tabulated on a conventional boiler test log. The conclusions reached by the plant engineers were very complete and only those that related directly to slagging are here given as follows:

UNTREATED COAL—"The test was started operating with 14.13 per cent CO_2, corresponding to 30 per cent excess air. The firing of this coal results in more slag formation than the West Virginia coal, the usual coal supply. Continual operation with the untreated coal without slag formation could be obtained only at the expense of increasing the excess air, hence decreasing the flame temperature and decreasing efficiency. The fly ash contained 16.35 per cent combustible matter."

TREATED COAL—"This test was followed without cleaning the tubes and operated at the start with 27 per cent excess air. In fact, the treated coal slag appeared

to flux off slag that was present previous to the start. After the hard, glassy, tough slag that was present before the test was removed, the clinker from the treated coal was porous, friable and easily handled by the sluice system. After 26 hr a slight reduction in the amount of slag on the tubes at the lower bend was observed. For the remainder of the test, the rating was maintained but the CO_2 was increased to 16 per cent (22 per cent excess air) without causing any further slagging of the tubes. The combustion with this low excess air was good, resulting in a clear furnace and good stacks. The fly ash contained 11.72 per cent combustible matter."

In the light of this experience there seems to be promise of a chemical approach to the problem of more efficiently burning the low-grade coals, in which our country abounds, by another step in the preparation of such coals at the mines to improve their burning characteristics.

Recovery of Germanium from Fly Ash

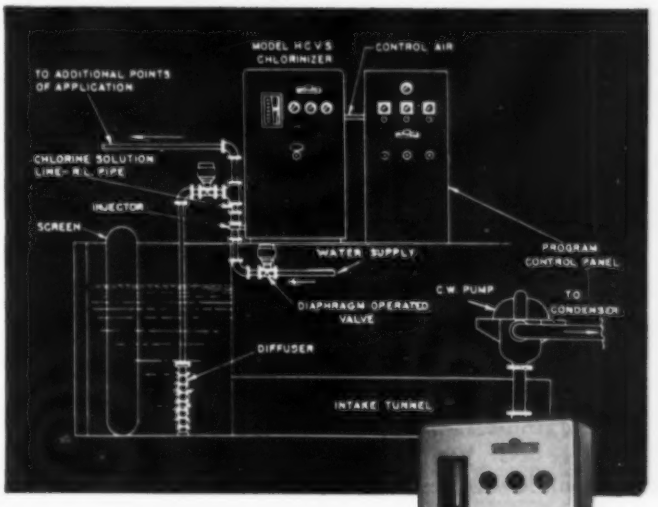
The element germanium, which formerly was little used and regarded more or less as a scientific curiosity, has lately found a heavy demand to meet electronic developments in radar and television receivers. The principal domestic source, heretofore, has been in zinc sulfide concentrate and in some lead-zinc mining by-products. It is never found in the free state. However, it has long been known that many coals contain germanium, and British investigations discovered appreciable concentrations in flue dusts from gas works and gas producers. In the United States the largest producer of this metal has employed by-products from zinc-smelting operations.

More recently, the U. S. Bureau of Mines, in conjunction with the U. S. Army Signal Corps., undertook a program of investigation to determine the feasibility of recovering germanium either directly from coal or from the products of the combustion of coal. However, since the concentrations in most coals are small, it was deemed more economical to process the ash from boiler furnaces of large coal consumers, such as public utility power plants. Thirteen such plants were selected, embodying pulverized coal firing, cyclone furnaces, and several types of stokers. The results are contained in a paper by R. C. Corey, J. W. Myers, W. A. Selvig and L. B. Berger which was presented at the Joint AIME-ASME Fuels Conference at Chicago, October 29–30, 1953.

The results show that most of the germanium in the coal fired by any of these methods is associated with the fly ash leaving the boiler. Generally, the germanium content of the fly ash ranged from 15 to 90 ppm, but the two richest fly-ash samples contained 290 to 530 ppm. A limited study of particle size gave evidence that the finer particles of fly ash are generally richer in germanium than are the coarser sizes.

With two exceptions, no germanium was found in the slag or refuse from furnace-bottom hoppers or slag pits. This suggests that the concentration of germanium in the fly ash should vary inversely with the proportion of the total ash that is discharged in the form of fly ash. It was generally concluded that if most of the germanium is volatilized and subsequently condenses on the fly ash, the smaller the quantity of fly ash, the richer it will be in the germanium compound.

Slime Control IN COOLING SYSTEMS



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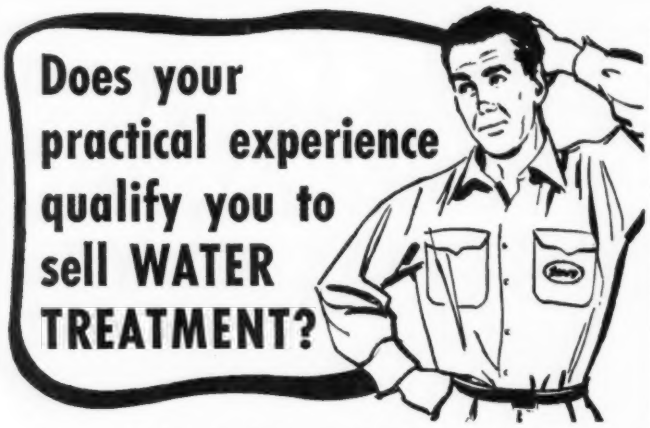

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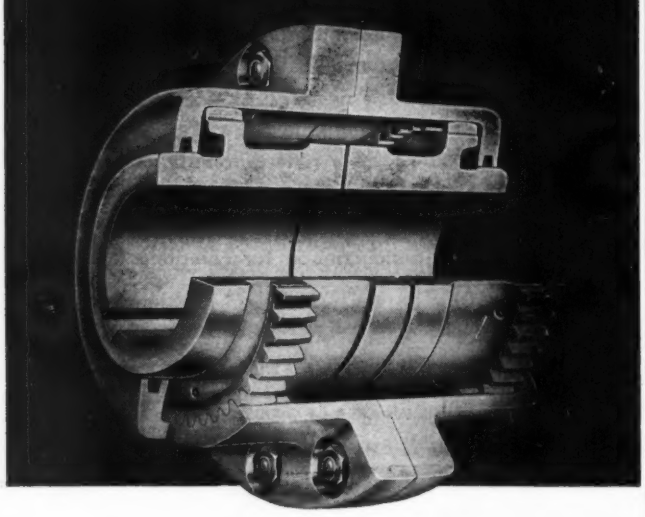

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Facts and Figures

Last year the United States produced nearly a third of the world's output of coal and lignite.

•

In the postwar period investments for new construction by electric utilities have been close to two billion dollars per year.

•

According to the Federal Power Commission, there are 288 privately owned electric utility companies operating in the United States.

The dredging of river anthracite in Pennsylvania has decreased to about a third of what it was ten years ago.

•

West Virginia, the nation's largest coal-producing state, also has the top coal-producing county—Logan—with an annual output of approximately 23 million tons.

Atomic energy projects now account for about three per cent of the total expenditures for new construction in the United States.

•

Four motors aggregating 216,000 hp are required to drive two compressors serving the propulsion wind tunnel of the U. S. Air Force at the Arnold Engineering Development Center at Tullahoma, Tenn.

•

Engineering and Boiler House Review (London) reports that there is a very active campaign on foot by the Labor Party in Britain for nationalization of the engineering industry, including coal mining machinery, heavy electrical plant equipment, machine tool manufacturing and aircraft.

•

Hourly earnings of bituminous coal miners in the United States during the current year averaged close to $2.50.

•

Large quantities of waste heat developed in the atomic reactors at the Hanford plutonium-producing plant will shortly be used for heating buildings.

•

Direct firing of pulverized coal was first employed commercially in boilers about thirty years ago.

•

A boiler that is to be drained and taken out of service should be flushed out to avoid sludge baked on the tubes.

•

The British Electricity Authority reports an average annual profit of slightly under 6 million pounds (approximately $16,800,000) for the electric utility industry in Britain since nationalization. However, with an output of 52 million kilowatt-hours for the past fiscal year, 1952–1953, the profit was increased to the equivalent of over 20 million dollars.

AIEE Fall General Meeting

THE Fall General Meeting of the American Institute of Electrical Engineers, held at the Hotel Muehlebach in Kansas City, Mo., November 2-6, incorporated a well-rounded technical program stressing the use and generation of electrical energy. Inspection trips were made to the dispatcher's headquarters for the 1056 mile, 20-in. line of the Platte Pipe Line Co. and to the Hawthorn Power Plant of Kansas City Power and Light Co. Approximately 1000 engineers were present for the meeting.

At a joint luncheon meeting with the Kansas City Chamber of Commerce, Elgin B. Robertson, president of AIEE, spoke on the role of the electrical engineer as it affected the everyday life of the public at large. Col. William Talbot, Director of Warning and Communication for the Federal Civil Defense Administration, was one of the principal speakers at the opening general session.

Protection of Turbines and Boilers

Four engineers from the Consolidated Edison Co. of New York, **H. A. Bauman, J. M. Driscoll, P. T. Onderdonk** and **R. L. Webb,** explained the protective scheme adopted for the new Astoria Generating Station of their Company. The basic concept is to prevent serious damage to equipment by immediate detection of abnormal conditions and automatic tripping out of equipment. Protection for the boiler, turbine and electrical system is coordinated so that troubles will cause complete or partial shutdown as may be demanded by the type of failure involved.

Protection is provided to take care of the following emergencies: thrust bearing failure, damage from excessive vibration, excessive temperatures in the exhaust hood and condenser shell, damage from loss of vacuum and excessive overspeed, generator and transformer protection, generator grounding and motoring, loss of generator field, short circuits in main and auxiliary feeders, failure of combustion air supply, excessive furnace pressure and fuel interruption.

The system is set up and interlocked so that the cause and location of the initial tripping is indicated on an annunciator board in the main control room. This is true even though many other devices may be tripped out following the initial impulse. Thus the source of initial difficulty can be identified in the control room.

Northeastern Outdoor Station

E. F. DeTurk and **W. J. Burns** of the Long Island Lighting Co. presented a paper entitled "Glenwood No. 3 Outdoor Power Station" in which they described the installation of two 90/99-mw outdoor turbine-generator units at Glenwood Landing on the north shore of Long Island. The boilers are of semi-outdoor construction, with the forced-draft fans located indoors and the induced-draft fans outdoors.

Design of the plant is predicated upon the unit principle with a single boiler, turbine-generator and step-up transformer. The turbine is a 90/99-mw Preferred Standard, 3600-rpm, 22-stage tandem-compound double-flow condensing unit having throttle conditions of 1450-psig, 1000 F with reheat to 1000 F. During construction the turbine-generator was protected by a temporary housing consisting of removable aluminum roof sections and canvas sidewall curtains mounted on a pipe-scaffold type structure. For regular operation a weather-proof housing has been provided over the exciter, turning gear and over the head end of the turbine.

The steam generating unit is tangentially fired with tilting burners and is designed to produce 750,000 lb of steam per hour at 1525 psig, 1005 F at the superheater outlet with reheat back to the initial temperature. The semi-outdoor construction provides transite enclosures at the burner elevations and at the drum and a brick enclosure around the forced-draft fans and ash hopper.

Coal, oil and natural gas can be burned interchangeably or simultaneously. Coal conveying facilities have a continuous capacity of 300 tons per hour. There is a coal storage yard with a capacity of 100,000 tons; two tanks having a total capacity of 147,000 barrels are available. Natural gas is supplied as surplus from the Company's gas-distribution operations.

The regenerative cycle in the plant includes two high-pressure and three low-pressure horizontal closed feedwater heaters of the U-tube type. Deaeration of condensate is carried out in the condenser.

A centralized control room which is air conditioned and sound proofed is located on the turbine operating deck. The control board is of the graphic type and shows all essential controls for the boiler, turbine-generator, auxiliaries and electrical switching. A number of auxiliary gage boards have been located at points where several

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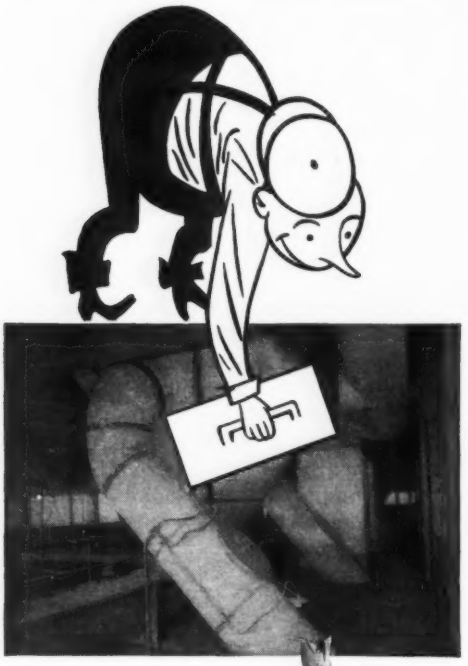

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controls and gages could be conveniently grouped.

The authors estimated a saving of $300,000 as a result of the outdoor arrangement, which also enabled a reduction in building volume to a value of 11 cu ft per kw.

Boiler Developments

In discussing boiler developments **G. V. Williamson** of Union Electric Company of Missouri noted the marked acceleration of boiler size. In the 1920's boilers were being built for 20,000-kw machines, while today single units are being supplied for 250,000-kw turbines and larger. He stated that some of the chief problems of designers are those of achieving and accurately controlling high steam temperatures and pressures. Because of higher boiler feedwater temperatures and the greater amount of heat going into superheat and reheat, there is a sharp reduction of total heat that can be absorbed by waterwalls.

Higher steam conditions also cause slagging problems. Three approaches to the temperature-slag condition are (1) radiant steam superheating surface in the side-walls, (2) recirculation of cooled flue gases to the top of the furnace and (3) radiant superheater surface either as platens or as pendant loops. Mr. Williamson also mentioned problems of circulation at high pressures and the effect of controlled circulation in permitting a wider range of furnace shapes and heights.

Turbine-Generators

Edwin H. Krieg of Stone & Webster Engineering Corp. summarized present and future developments in turbine-generators, noting that there are at least eight major types available for central station service. The choice of type may be dictated by the capacity desired or by costs which vary widely between types, 3600 rpm tandem-compound units usually being cheaper (but with higher heat rate) than the cross-compound type. Each type presents a wide selection of steam pressures and initial temperatures, while larger sizes also are available with and without reheat and cover two or three different lengths of last stage blades.

Single units are on order up to 250 mw; 300 mw designs are ready, and 500 mw cross-compound units could be ordered if needed. One turbine is being built for steam conditions of 4500 psig, with 1150 F throttle temperature and two stages of reheat.

Controls are provided to insure proper starting and operating characteristics as well as safety and removal from service under emergency conditions that may be encountered.

Turbine generator first costs depend on type and steam conditions, while operating costs are usually quite low as few operators are required and turbines are often unopened for four years or more.

Availabilities of over 92 per cent have been reported over a ten-year period, and a number of units have achieved 96 per cent.

Gas Turbines

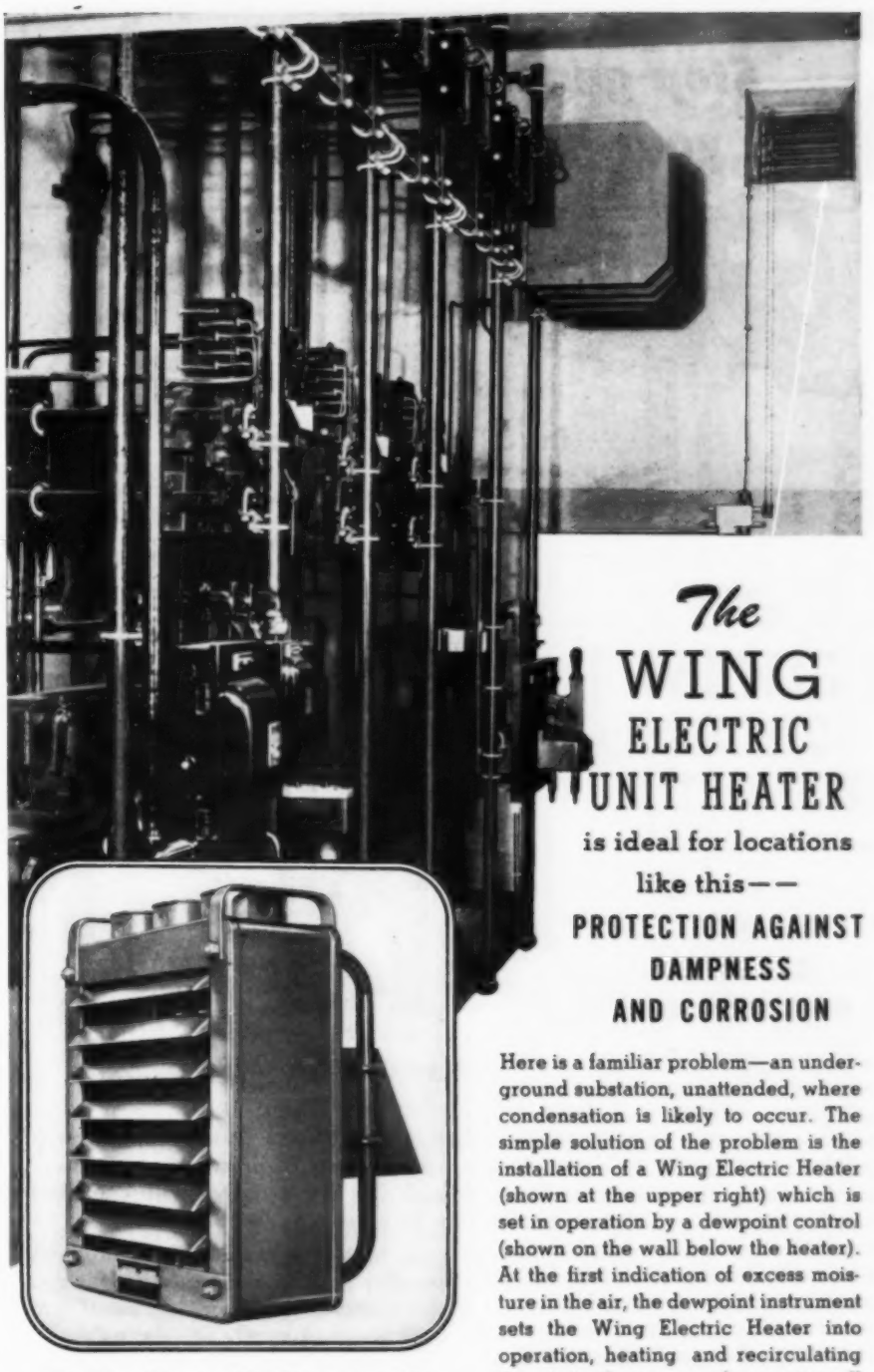
A review of the current status of the gas turbine as a prime mover was presented by **C. F. Kottcamp** of Gulf Oil Corp. In the United States, as of August 1953, gas-turbine operating experience totaled approximately 170,000 hours. According to the author, type of fuel is the most important single factor related to future commercial potentialities of the gas turbine. Considering the thermal efficiencies of units now in service, a low cost fuel is very important for the gas turbine if it is to be competitive on a fuel cost basis with established power generation cycles. For units up to 5000 kw the gas turbine should use either fuel oil or coal. For units in the 10,000–15,000 kw range, the low cost fuel factor may be less important as related to initial capital investment and operating costs, partly because of the higher thermal efficiency which may be realized.

Gain in Utility Output and Capacity

The installed capacity of electric generating plants in utility service as of September 30, 1953 was 87,588,024 kw, according to reports received by the Federal Power Commission during October. This compares with 78,757,545 kw as reported in service on September 30, 1952, making a gain of nearly 9 million kilowatts during the twelve-month period.

The total utility production during September 1953 exceeded 37 billion kilowatt-hours and was the highest for that month on record, although 3.8 per cent under the total for August. Water power was responsible for only 20.5 per cent of the total output. The twelve months total utility output from all sources exceeded 434 billion kilowatt-hours and was 10.9 per cent above the corresponding twelve-month period a year earlier.

Industrial plant generation for September 1953 was nearly 5.9 billion kw-hr in September and industrial generating capacity was reported as 15,723,000 kw. This made a combined utility and industrial generating capacity of over 103 million kilowatts.



The Wing Electric Unit Heater is made in three types—the Utility Heater shown above, the Wing Revolving Overhead, Downward Discharge Unit Heater and the Wing Electric Duct Heater Section. Sizes from 13,600 Btu/hr to 204,000 Btu/hr.

Write for a copy of Bulletin E-1

The WING ELECTRIC UNIT HEATER is ideal for locations like this——

PROTECTION AGAINST DAMPNESS AND CORROSION

Here is a familiar problem—an underground substation, unattended, where condensation is likely to occur. The simple solution of the problem is the installation of a Wing Electric Heater (shown at the upper right) which is set in operation by a dewpoint control (shown on the wall below the heater). At the first indication of excess moisture in the air, the dewpoint instrument sets the Wing Electric Heater into operation, heating and recirculating the air in the room and removing all danger of dampness and corrosion.

Wing Electric Heaters have many applications, not only in the electric utility field, but wherever heat is necessary at remote points or where steam or gas is unavailable or uneconomical.

Wing

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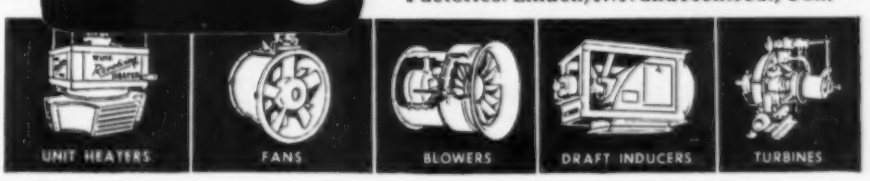
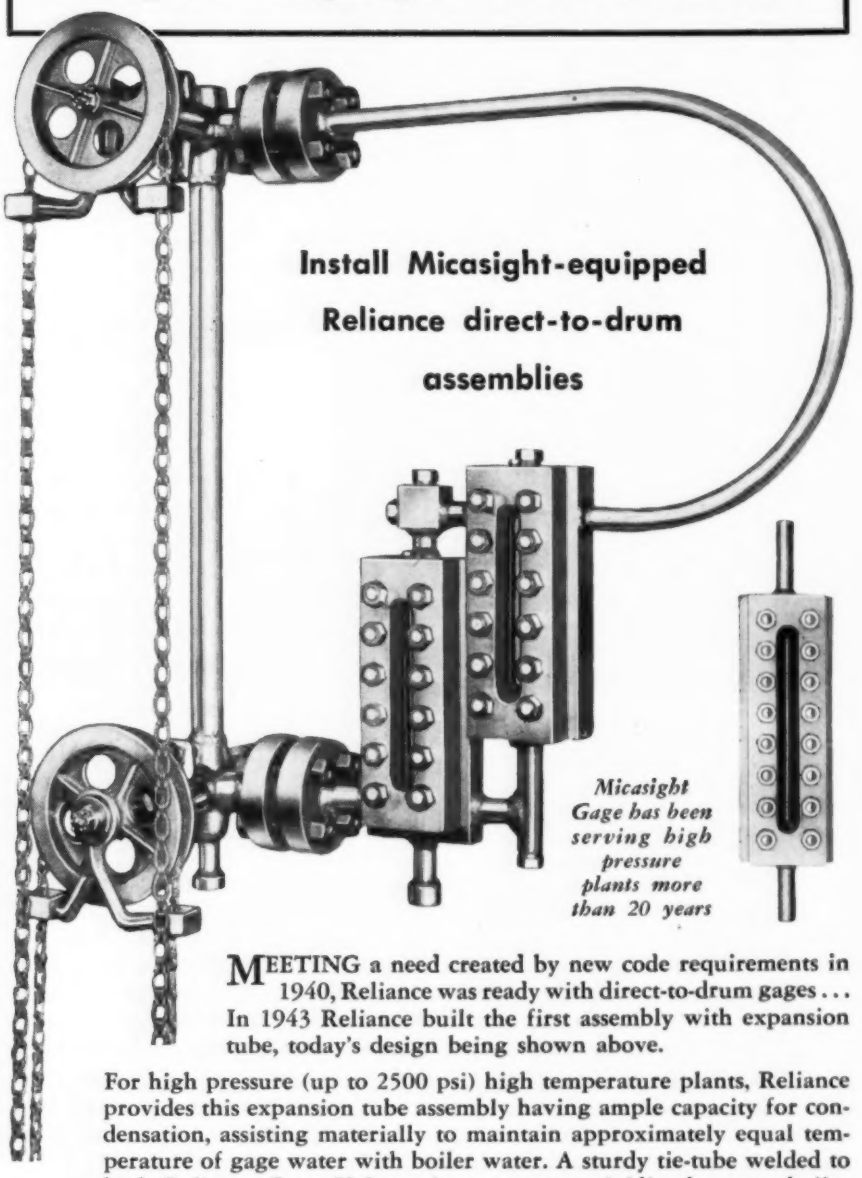
Factories: Linden, N.J. and Montreal, Can.



Stop gage glass breakage on your high pressure boilers



Install Micasight-equipped Reliance direct-to-drum assemblies

Micasight Gage has been serving high pressure plants more than 20 years

MEETING a need created by new code requirements in 1940, Reliance was ready with direct-to-drum gages... In 1943 Reliance built the first assembly with expansion tube, today's design being shown above.

For high pressure (up to 2500 psi) high temperature plants, Reliance provides this expansion tube assembly having ample capacity for condensation, assisting materially to maintain approximately equal temperature of gage water with boiler water. A sturdy tie-tube welded to both Reliance Gage Valves gives necessary rigidity between boiler connections. Reliance all-welded gage assemblies have more than sufficient ruggedness to meet severest conditions.

Extra gage-reading safety and long window life is assured by the exclusive Micasight Gage which uses non-shattering mica windows securely clamped in short, wide-bar, non-breathing bodies. Reliance provides access to clean out all passages, with entrances guarded by non-freezing plugs. Gage is connected to valves by ring-joint flanges — no nipples or packing glands. The Micasight is the safest water gage known. *Write for full information, to the factory or your nearest Reliance representative.*

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BOILER SAFETY DEVICES

New Books

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Temperature Measurement in Engineering

By H. D. Baker, E. A. Ryder and N. H. Baker

This is the first of two volumes discussing temperature in terms of engineering measurements. It is the outgrowth of a project initiated by the late Charles E. Lucke and is predicated on experience attained in the mechanical and physical laboratories at Columbia University.

The text is nonmathematical and presents practical detailed instructions for measuring temperature. In the present volume this has to do largely with thermocouple measurements, under various conditions involving circuits, thermocouple wire, junctions and splices, insulation, calibration, types of couples and their application. Extensive references to published material are incorporated.

The second volume will deal with problems of the measurement of very low and very high temperatures; temperatures of liquids and gases, rapidly moving bodies, flames, etc.

Judging from a perusal of this first volume which covers 179 pages and is priced at $3.75, the work fulfills a long-felt need by those who are regularly or occasionally engaged in field or laboratory testing that involves temperature measurements.

Energy in the Future

By Palmer Putnam

This book embodies the results of a study by the author, under contract with the U. S. Atomic Energy Commission, with reference to the probable demands for energy during the next fifty to one hundred years and the ability of nuclear and non-nuclear fuels to meet these demands with reasonable economy.

Starting with a study of population growth over the years and projecting this into the future, the author arrives at a figure of 3.7 billion as the plausible world population in the year 2000 A.D., of which the United States would have some 300 millions.

Since 1935 the world increase in energy output per capita has averaged about 3 per cent a year, and it is shown that if the United States should continue to consume about a third of the world total energy supply, as it does at

present, an annual demand by 2000 A.D. would likely approximate $150{,}000 \times 10^{12}$ Btu.

The study goes into the question of how much longer we can live off capital energy and takes a look at recoverable reserves of coal, oil, gas, oil shale and tar sands, finally examining the likely rôle of nuclear fuels in supplying low-cost energy.

An extensive bibliography of over 50 pages lists the sources of information consulted as well as the names of some 125 specialists who either contributed information directly or by way of reviewing the text in its initial form.

The book is the most exhaustive study of its kind that has been undertaken. It represents a long-range view that many will find both fascinating and very valuable as a reference, and particularly as a basis for economic studies. It is most timely at present when energy demands are increasing at a rate that demands re-examination of our fuel resources, and when we appear to be on the threshold of nuclear power application.

There are 556 pages and the book is priced at $12.75.

High-Temperature Alloys

By Claude L. Clark

This is a book intended for those who develop and use high-temperature alloys. It is also suitable for use as a text and reference book and should be of considerable assistance to those organizations having high-temperature testing laboratories. The approach is basically a metallurgical one

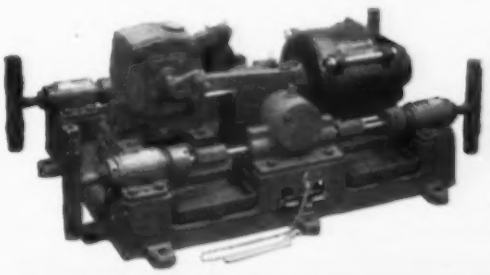
An introductory chapter takes up industrial trends which have prompted interest in high-temperature alloys. Next are considered the mechanism of plastic deformation, desirable qualities for high-temperature service, and methods of testing. Considerable attention is given to creep strength and to methods for evaluating load-carrying ability. The largest portion of the book concerns properties of various alloy steels, including low and intermediate alloys, stainless steels, bolting steels and those for extreme high-temperature service. There is a very interesting chapter covering nine types of service failures. Concluding chapters take up physical constants, properties at hot-processing temperatures, selections of material for specific applications, and typical specifications and codes covering high-temperature steels.

There are 383 pages in the book which sells for $7.50.

Here's a handy guide to the selection of metering and proportioning pumps

In this new catalog and pump selection manual for Hills-McCanna "U" Type Metering and Proportioning Pumps is all the information, including prices, for the selection of exactly the right pump for handling over 300 substances. Clearly and concisely, this helpful booklet gives all the necessary information and specific recommendations to cover the vast majority of needs that can be filled with a Hills-McCanna "U" Type Pump.

If your operations involve the metering or proportioning of small volume flows, you will find this catalog a useful addition to your files. We will be pleased to send you a copy on request. HILLS-McCANNA COMPANY, 2468 W. Nelson St., Chicago 18, Illinois.



Hills-McCanna "U" Type Pumps are reciprocating, variable stroke, mechanical drive units with maximum capacities ranging from 0.10 to 24 gph. per feed. One, two, three and four feed assemblies are available. Operating pressures up to 5,000 psi. A four feed unit is shown at the left.

HILLS-McCANNA

metering and proportioning pumps

Also Manufacturers of: Saunders Patent Diaphragm Valves Force Feed Lubricators • Magnesium Alloy Sand Castings

French Power Resources and Consumption

That France is not well provided with fuel and power resources, with the exception of water power, and has to import nearly all the petroleum and a large part of the coal consumed within her borders, was brought out in a paper by J. Couture before the Institute of Fuel (British) on November 5.

The production of petroleum amounts to only about 2 per cent of the consumption, hence the 1952 importations of refined products amounted to 22 million tons. French coal fields produced 57.5 million tons of coal last year and 18.5 million tons were imported. There is only one deposit of natural gas, that at St. Marcet, the annual output of which amounts to approximately one billion cubic feet.

Much renovation and extension is being undertaken at the colliery power plants in order to utilize the middlings and slurry in pulverized form. When the present program is completed these colliery power plants will have a combined rating of 2,300,000 kw, which figure is expected to increase to 12,000,000 kw by 1960.

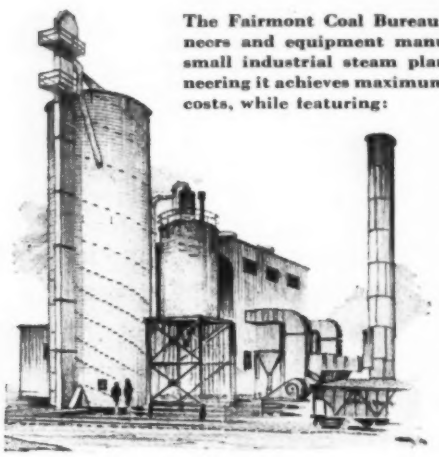
Electricity Consumption Doubles

The total consumption of electricity, omitting transmission losses, rose to 40.8 billion kilowatt-hours in 1952, which was about double that in 1938. Although subject to seasonal variations, water power normally supplies approximately half the total. Some of this is supplied by barrage schemes. It has been estimated that the total potential hydro power is of the order of 80 to 90 billion kilowatt-hours annually.

Progress in the design of steam stations is expected to reduce greatly the expenditure of fuel. Large units are now the rule with pressures of around 1400 psig and 1000 F. In fact, French and other European manufacturers are now supplying steam and electrical power equipment comparable with that lately imported from the United States. The present construction program is chiefly concentrated in the neighborhood of the mines and in the Paris area.

Modern Design *for the*

MODERN COAL



The Fairmont Coal Bureau has made available to consulting engineers and equipment manufacturers a TYPICAL DESIGN for the small industrial steam plant. Prepared as a guide to good engineering it achieves maximum economy of investment and engineering costs, while featuring:

- Fuel flexibility
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Fairmont Pittsburgh Seam Coal is the MODERN COAL. Enormous reserves and inherently favorable mining conditions guarantee ample supply and low production cost. Modern mining and preparation facilities assure uniform quality.

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Removes and Prevents Scale, in Boilers, Condensers, Evaporators, or any heat-exchange surfaces especially where chemical processes have failed. Priming and carryover positively prevented.

Corrosion in condensate return lines due to low pH, corrected by the addition of

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High pH and slight oil contamination of Boiler Water, corrected by

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Openings for Representatives in Several Territories

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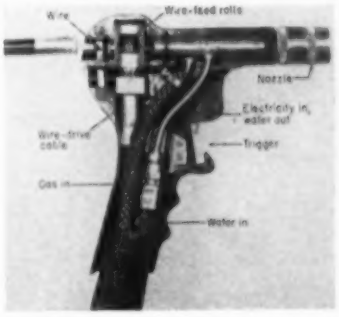
New Equipment

Gas-Shielded Welder

New welding equipment for the consumable-electrode gas-shielded welding process has been announced by the Welding Department of General Electric Co., Schenectady 5, N. Y. Known as Fillerarc, it provides high-speed metal deposition which enables the operator to more than double output on applications where filler metal must be added.



Electrode wire of aluminum, stainless steel, mild steel, copper, magnesium and other alloys may be employed with argon or helium shielding gas. The welding gun contains knurled feed rolls and is capable of feeding wire from 0.030 to 0.093 in. in diameter.

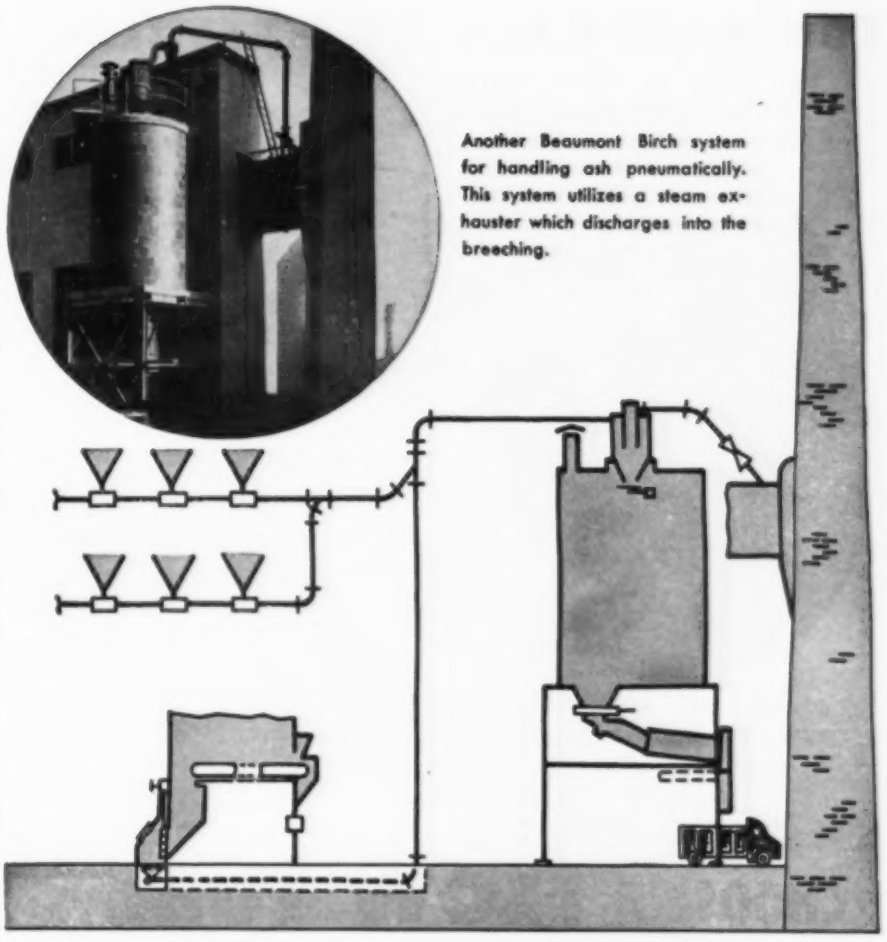
Retracting Blower

For cleaning extremely wide boilers where the blower nozzle must travel more than 25 ft, Diamond Power Specialty Corp., Lancaster, Ohio, has developed the Model TT blower. Among its features are the rigid truss construction for simple support and step-tapered lance for minimum deflec-

tion. A single stationary motor mounted at the boiler end both propels and rotates the lance tube through a close-pitched blowing pattern for high-intensity and uniform cleaning. There is a mechanically operated poppet-type supply valve which can handle either air or steam as the blowing medium.

Silencers

Two new series of silencers for quieting the noise produced by air compressors, blowers, vacuum pumps and other machines have been developed



Another Beaumont Birch system for handling ash pneumatically. This system utilizes a steam exhauster which discharges into the breeching.

PNEUMATIC ASH HANDLING

by Beaumont BIRCH

Low cost automatic ash disposal at high rates

The pneumatic ash handling system shown above is only one of the many bulk material handling systems in Beaumont Birch's complete line.

For 50 years, Beaumont Birch has installed thousands of coal, ash, and bulk chemical handling systems under all types of limitations. This wide experience assures you the *right* system to fit *your* requirements. Each installation is individually engineered to assure lowest possible cost, and to provide maximum service life of equipment with minimum maintenance.

For most of its existence, Beaumont Birch has had the distinction of being the only source of coal, ash and bulk materials handling equipment under one contract. This undivided responsibility assures you a coordinated system at less cost, appreciable savings in time and efficient operation.

Why not call in a Beaumont engineer on your next bulk materials handling problem.

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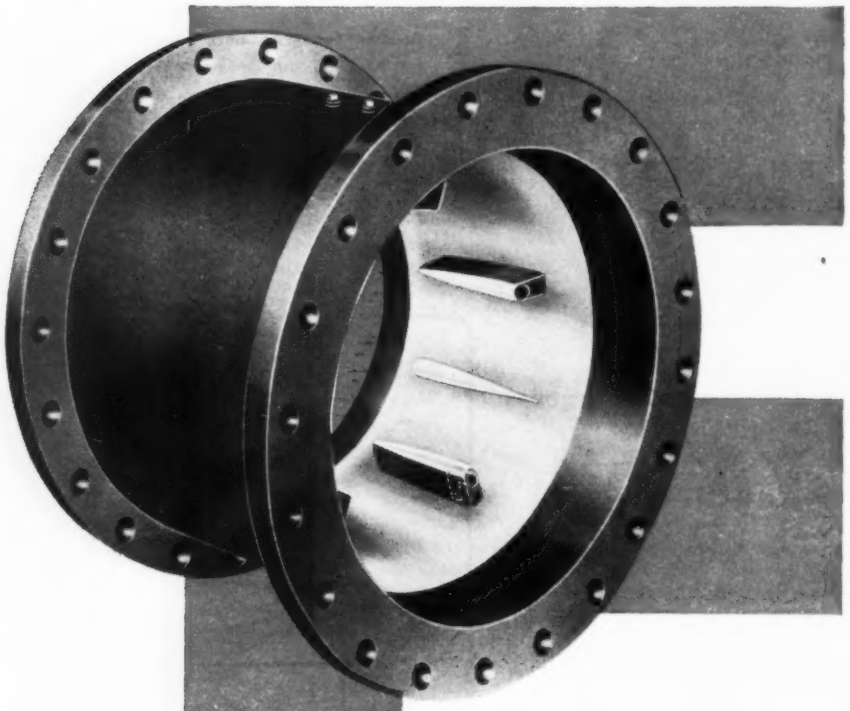
DESIGNERS—MANUFACTURERS—ERECTORS BULK MATERIAL HANDLING SYSTEMS

FOR ACCURACY IN METERING



CHOOSE A FLOW TUBE

Flow Tubes are furnished with head capacity curves based on laboratory tests. For unusual piping arrangements, special tests can be run simulating actual conditions. The data furnished with each Flow Tube makes exceptional metering accuracy possible.

Flow Tubes have many other plus values — they're compact, comparatively light weight, and are easy to install since they require minimum straight runs entering and following. And, Flow Tubes are available in types and D/d ratios to provide differentials that can be accurately measured with the least head loss.

That's why Flow Tubes are being successfully used in scores of installations metering the flow of liquids and wet or dry gases. Available in all pipe sizes and suitable metals. They can be furnished with or without suitable secondary indicating, recording or totalizing instruments. Write for further information. For specific recommendations, send us necessary flow data.

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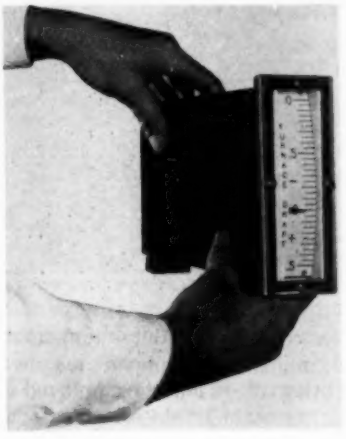
FOSTER ENGINEERING COMPANY • UNION, N. J.

by the Burgess-Manning Co., Libertyville, Ill. They are absorption-type silencers employing straight-through perforated tubes surrounded by a deep layer of sound-absorbing material. Special material can be used for operation at temperatures higher than the standard of 200 F.

Draft Gages

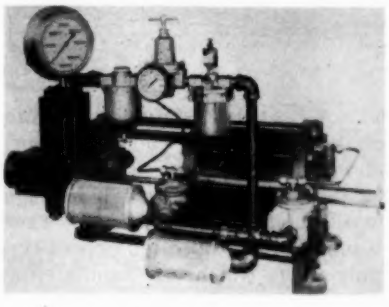
A bantam gage for measuring draft, pressure, vacuum or differential draft has been announced by Republic Flow Meters Co., 2240 Diversey Parkway, Chicago 47, Ill. With a face $6^{7}/_{16}$ in. high, this direct-measuring gage is suitable for use on compact console and



graphic panels. As many as eight gages may be mounted in a single case. Diaphragm elements are available for pressures as low as 0.6 in. and as high as 40 in. of water. The gage can also be furnished with two bellows and two pointers for steam flow-air flow or fuel-air indication.

Hydraulic Pump

The Aldrich Pump Co., Allentown, Pa., announces production of a new air-driven hydraulic pump which is available in single- or double-acting models. It is a simplex horizontal type which



develops up to 20,000 psi operating on 90-psi air supply. The pump is intended for such applications as testing tubing, valves and pressure vessels and to supply power for small molding presses.

Personals

Eugene L. Hough has been elected a vice president of the Union Electric Company of Missouri. He was also reappointed chief engineer of the Company, a position he has held since 1951.

H. H. Levonian has been appointed vice president in charge of construction for the Kuljian Corp., Philadelphia engineers and constructors. For the past twenty-four years he has been identified with the building of power and chemical processing plants in this country and abroad.

Alden E. Calkins has been named publicity and public relations representative of Stone & Webster, Inc. His office is at 250 Fifth Avenue, under his own name.

F. S. Mallette, executive secretary of the Committee on Air Pollution Controls and staff member of the American Society of Mechanical Engineers, has been invited to deliver the annual Clayton Lecture before the Institute of Mechanical Engineers (British) in London on April 23, 1954. He will talk on air pollution.

Howard V. Barr has been named manager of the new 175-million dollar Clifty Creek Steam-electric generating plant now under construction on the Ohio River at Madison, Ind. This station is being built by the Indiana-Kentucky Electric Corp., a subsidiary of the Ohio Electric Corp. which was formed by a group of fifteen private electric utility companies to supply power to the Atomic Energy Commission's new Portsmouth Area Project.

Felix W. Saco, formerly of the mechanical engineering department of Permutit Co., has been made development engineer in charge of developing the Company's line of industrial products.

Viscosities of Natural Gas Components and Mixtures

Results of the experimental determination of the absolute viscosity of methane and three natural gas mixtures at pressures up to 10,000 psi, and temperatures from 70 to 250 F, are presented in Institute of Gas Technology Research Bulletin No. 23, "Viscosities of Natural Gas Components and Mixtures," by N. L. Carr.

The data, which are important in many calculations involving fluid flow, particularly in the flow of gas out of or into underground reservoirs, and in pipeline transmission, are presented in this 60-page, $5.00 bulletin.

NATIONAL AIROIL

Oil Burners

OF THE STEAM AND MECHANICAL TYPES NOW COMBINED INTO

Dual Stage BURNERS

Now, at last, the inherent advantages of *both* systems of fuel oil atomization are *profitably* yours . . . within the one, new NATIONAL AIROIL Dual Stage Burner.

41 years of combustion equipment design and manufacture are in back of the Dual Stage Oil Burner . . . and, it has been thoroughly tested and proved in the field for firing: Petroleum Processing Heaters; Rotary Kilns; H.R.T., Scotch Marine and Water Tube Boilers; etc.

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Get detailed description, illustration, and specifications in NATIONAL AIROIL Bulletin 25.

OIL BURNERS and GAS BURNERS for industrial power, process and heating purposes
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MECHANICAL PRESSURE ATOMIZING OIL BURNERS
DUAL STAGE, combining Steam and Mechanical Atomization
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AUTOMATIC OIL BURNERS, for small process furnaces and heating plants
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Business Notes

The William Powell Co., Cincinnati, has appointed Lee E. Cearnal as its sales representative for the southern part of Georgia, South Carolina and all of Florida except west of the Appalachicola River; also Carl L. Noe who will be located in Mobile and cover southern Alabama, southern Mississippi and the western "panhandle" of Florida.

Elliott Company has named F. Q. Wilson as its New York district manager with offices at 271 Church Street.

Bigelow-Liptak Corp. has shifted L. E. Brungraber from its New York City sales office to Philadelphia and Arthur H. Trinkle from Detroit to New York City.

E. F. Drew & Co. has named M. E. Reiner division manager to direct activities of its Power Chemicals Division. As a specialist in industrial water problems, he will supervise the international network of the Company's power chemical field offices.

Edward Valves, East Chicago, Ind., has appointed Rex E. Galloup district manager for the Texas and Gulf Coast area. His headquarters will be in Houston, Texas.

General Electric Co. announces the appointment of Kenneth G. Patrick as manager of educational relation services. He will be succeeded in his former position as manager of general public relations by J. Stanford Smith. In turn, Ralston B. Reid has been named to replace Mr. Smith as manager of advertising and sales promotion for the Apparatus Sales Division.

The Euclid Road Machinery Co., Cleveland, announces the following promotions within its organization: V. L. Snow, formerly manager of domestic sales to director of sales; J. E. Ehlert to succeed Mr. Snow; and P. H. Malenchini as manager of export sales. Robert J. Lenz has been made manager of the Customer Service Department.

Diamond Power Specialty Corp. has just moved into its new electronics laboratory which is adjacent to its manufacturing plant at Lancaster, Ohio. The laboratory will be used for continuing development of the "Utiliscope" (wired television) as well as other electronic installations and controls.

The Committee for Economic Development has as its new chairman for information, Gardner Cowles, president of the Des Moines Register & Tribune and Cowles Magazines, Inc.

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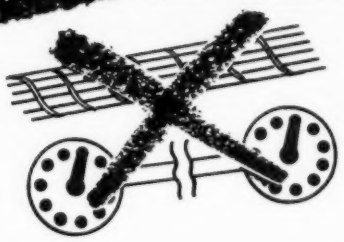
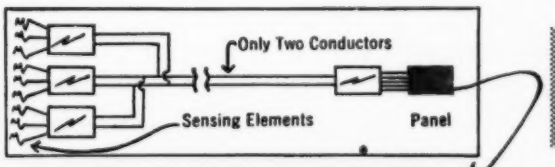


ELECTRONIC SCANNING
Completely Non-Mechanical and
utilizing only two conductors



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- Utilizes one inexpensive RG-59/U coaxial cable instead of 200 conductors in an average installation of 100 points.

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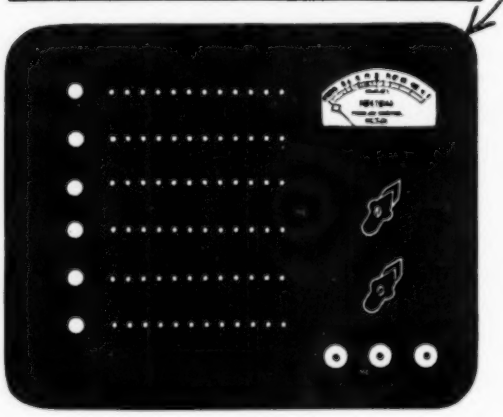
- Alarm and meter indicate failure of any circuit element.



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BOOKS

1—The Technique of Clear Writing

By Robert Gunning

289 pages Price $3.50

The author of this book has had outstanding success as a readability consultant and his firm has conducted readability surveys for the United Press and Newsweek. It has also been responsible for clear writing training for such organizations as Standard Oil of New Jersey, B. F. Goodrich Company and the Baltimore and Ohio Railroad.

Knowing this background, the practicing engineer should approach this practical guide to writing with an idea something like this: he is capable of writing clear and convincing reports if he is only wise enough to apply the outlined principles thoughtfully.

The book opens with chapters telling what has been learned about the habits and preferences of readers. Then follows the second and longest part of the book in which ten principles of clear writing are elucidated. Part three has chapters entitled "The Fog in Your Newspapers," "Business Writing," "Legal Prose" and "Technical Writing."

For the engineer who wishes to write effectively the last chapters mentioned above deserve rereading several times. The author points out that the men of science most venerated are those skilled in communication.

He writes that most technical men and women talk clearly and concretely and are able to explain complex matters to a layman when they speak in oral communication. It is only when they begin to write that they shun simple English and slip into an odd jargon that they consider traditional and wise.

2—Coal Manual for Industry

By A. Wyn Williams

324 pages Price $5.50

This is a very readable, moderately technical presentation of information of interest to anyone having to deal with the purchase, handling and burning of coal.

Starting off with chapters on the physical and chemical properties of coal and the combustion process, the book is then arranged to describe the various conventional coal-firing systems. Later chapters take up problems of air pollution, methods of coal preparation the uses of lignite and anthracite, ways for handling the storing coal, and criteria for its purchase (including elements of typical contract specifications).

For the purchasing agent, the operating engineer who wishes to broaden his knowedge of coal utilization, or the engineering manager whose activities only are occasionally concerned with the design or operation of power plants, this book is to be highly recommended.

3—Handbook of Engineering Fundamentals
Second Edition

Edited by O. W. Eschbach

$5^1/_2$ x $8^1/_2$ Price $10.00

The first edition of this handbook brought out in 1936 established its place in engineering literature. In the present, or second, edition all fourteen chapters have been completely revised and expanded with the result that the total text has been enlarged by about 25 per cent.

The book is the work of some forty contributors, each a specialist in his particular field, under the editorship of Professor Eschbach who is dean of Northwestern Technological Institute, Evanston, Illinois.

Contents, by sections, include mathematical and physical tables; mathematics; physical units and standards; mechanics of rigid bodies; mechanics of deformable bodies; mechanics of incompressible fluids; aerodynamics; engineering thermodynamics; electricity and magnetism; radiation, light and acoustics; chemistry; metallic materials; non-metallic materials; and engineering law.

4—Steam Power Plants

By A. H. Zerban and E. P. Nye

524 pages Price $7.50

Intended basically for junior and senior students who have had some previous work in heat power, the text has three objectives:

1. To utilize fundamental principles of science toward the art of heat power engineering.
2. To bring to the attention of the student the economic factors that influence engineering decisions.
3. To give a general picture of the steam-power equipment of representative manufacturers.

The book includes chapters on power plant cycles, fuels, combustion, steady state heat transfer, furnace heat transfer, steam generators, steam power movers, fluid handling, instruments and controls, and internal combustion power plants.

5—Advanced Mathematics in Physics and Engineering

By Arthur Bronwell

475 pages Price $6.00

In preparing this text which is intended primarily for students in engineering and physics at the senior and graduate level, the author was guided by the following principles:

1. To present a fairly complete explanation of those areas of advanced mathematics which make up the principal analytical methods of physics and engineering.
2. To provide a broad perspective of the physical sciences through an understanding of a few fundamental mathematical formulations in those fields common to engineering and physics.
3. To offer an opportunity to become aware of the strong underlying unity in methods of mathematical analysis in many areas of physics and engineering.

The first five chapters take up complex numbers, infinite series, solutions of ordinary differential equations, and Fourier series. There follow chapters on partial differentiation, vibration phenomena, Lagrange's equations and vector analysis. Subsequent chapters are concerned with wave equation solutions, heat flow, fluid dynamics, electromagnetic theory, functions of a complex variable, and Laplace transformations.

This is a book well worth serious self-study by engineers whose mathematical education ended at the calculus level.

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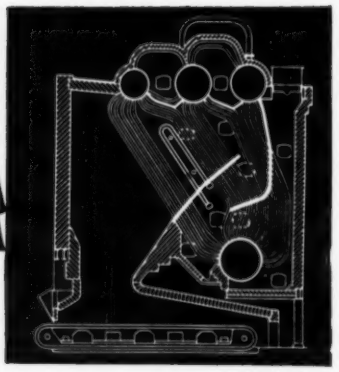

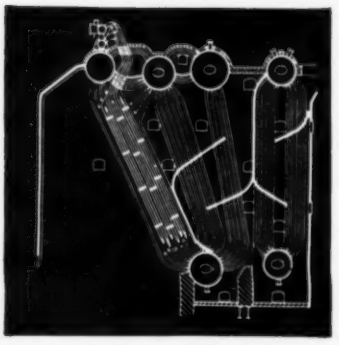

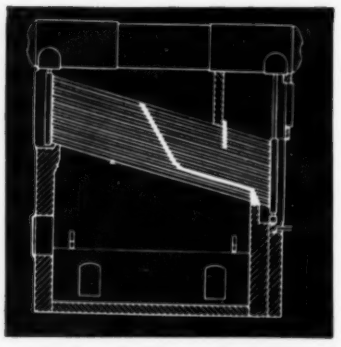

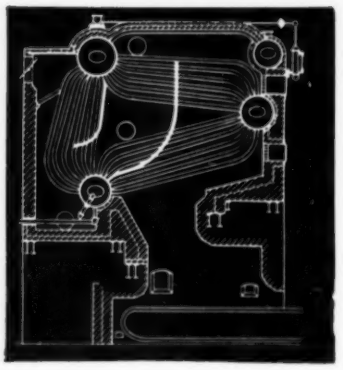

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Advertisers' Index

Aerotec Corporation, The..... 15
Air Preheater Corporation, The 8
Allis-Chalmers Manufacturing Company..... 78
American Blower Corporation .....33 and 34
Armstrong Machine Works.... 82

Bailey Meter Company..... 7
Baltimore & Ohio Railroad.... *
C. O. Bartlett & Snow Company, The..... 31
Bayer Company, The..... 22
Beaumont Birch Company.... 73
Belco Industrial Equipment Division, Inc..... *
W. H. & L. D. Betz..... *
Bigelow-Liptak Corporation... 17
Bituminous Coal Institute.... 26
Buell Engineering Company, Inc..... 46
Buffalo Forge Company..... 9
Builders-Providence, Inc..... 65

Cambridge Instrument Company..... *
Carborundum Company, The. 6
Chain Belt Company..... *
Clarage Fan Company..... *
Cochrane Corporation..... *
Coen Company..... *
Combustion Engineering, Inc. .....Second Cover, 20 and 21
Combustion Publishing Company, Inc..... 83
Copes-Vulcan Division, Continental Foundry & Machine Company.....12 and 13
Crane Co..... 79

Dampney Company, The..... 85
Dearborn Chemical Company 66
Diamond Power Specialty Corporation.....Third Cover
Dowell Incorporated..... *
E. F. Drew & Co., Inc..... 62

Eastern Gas & Fuel Associates 19
Edward Valves, Inc..... *
Engineer Company, The..... 84
Enos Coal Mining Company, The..... *
Ernst Water Column & Gage Company..... 72
Euclid Road Machinery Company..... *

Fairmont Coal Bureau..... 72
Flexitallic Gasket Company... 38
Foster Engineering Company.. 74

General Electric Company.... *
Graver Water Conditioning Company..... 16
Green Fuel Economizer Company, Inc..... *
Grinnell Company, Inc..... *

(Continued on page 85)